APPLICATION OF CHARGE SIMULATION METHOD FOR ESTIMATION OF HIGH VOLTAGE FIELDS

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CERTIFICATE

This is to certify that the work presented in this thesis entitled "APPLICATION OF CHARGE SIMULATION METHOD FOR ESTIMATION OF HIGH VOLTAGE FIELDS" submitted by Ajay Arora has been done under my supervision and it has not been submitted elsewhere for a degree or diploma.

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ABSTRACT

The subject for estimation of HV fields gained importance ever since the beginning of Electrical Engineering by the advent of digital computers. The conventional method for the estimation like field sketching by hand and by electrolytic tanks gave up their way. Numerical methods like FDM & FEM found their breakthrough in this field, however, a revolutionary change was brought up by Steinbegler in the late 1960's when he introduced CSM, a method most appropriate and suitable for the estimation of electric field between complicated unsymmetrical electrode configurations. Although this method is being used in practice in advanced countries it has just made a breakthrough in India.

In this thesis computer programmes using CSM have been developed for simple electrode configuration having rotational symmetry and involving one and two dielectrics. Also, basic mathematical background such as plotting of equipotential surfaces, for finding vertical and horizontal components of electric fields on arbitrarily inclined interfaces and arbitrary location of simulation charges etc. has been developed for further work in this field. Certain missing links in the existing theory have been found out.

Thus this work can provide a good starting for tackling complicated electrode configuration and involving multidielectric cases.

CONTENTS

APPLICATION OF CSM FOR ESTIMATION OF HV FIELDS

INTRODUCTION

The optimum design of insulation in high voltage apparatus between phase and earth is based on the knowledge of electric field distribution and the dielectric properties of the combination of insulating materials used in the system. The principal aim is that the insulation should withstand the stresses with adequate reliability and at the same time the insulation should not be overdimensioned.

The withstand voltage of the insulation of apparatus design with non-self-restoring insulation is determined by the field intensity developed at any point at the sparking gap on the electrodes. Corona discharge can be eliminated by employing properly designed high voltage shielding electrodes. Corona threshold voltage of shielding electrodes is a parameter which governs the radio and TV interferences and also in most cases the breakdown of the insulation between the electrode arrangement. Therefore, it requires a comprehensive study of the characteristics of corona discharges of the high voltage electrode system.

The pre-estimation of the electric stresses makes it possible to design apparatus with a high withstand voltage, free from corona discharge and generating low electric stresses and even resulting electric field low enough to

provide sufficient safety margin against insulation failure. Corona discharge magnitude and surface flux density of an existing electrode system can be determined experimentally with moderate accuracy but the pre-estimation of the electric stress magnitude at operating voltage can be calculated accurately with the help of computation before finalization of shield design.

Several methods are used today to calculate electric field either analytically or numerically.

For estimating electric fields, analytical solution of Laplace's equation can be obtained for relatively simple conductor configurations. However, field distributions of some of the geometries that are frequently used in high voltage apparatus, cannot be expressed in simple analytical terms.

As an alternative to purely analytical techniques, numerical methods are often used to solve such problems. These include the Finite Difference Method (FDM), the Finite Element Method (FEM), and the Charge Simulation Method (CSM).

FDM & FEM are directly based on the differential form of the Maxwell's equation. Solving differential equations either analytically or numerically involve difficulties inherent in

the formulation of inaccuracies arising within numerical procedures. These methods are also quite time consuming. On the other hand CSM is relatively simple as field strengths can be calculated analytically with reasonable accuracy because HV apparatus curved surfaces are generally preferred over sharp edges. It is also less time consuming for many geometries in HV technology.

This thesis work describes the application of CSM for some simple rotation symmetry fields as a numerical extension of image charge method (used for calculation of electric fields analytically for some simple configurations), thus, eliminating the need for formal solution of Laplace's and Poisson's equations in differential form.

CHAPTER 1

THEORY & DISCUSSION

1.1 Image charges and their applications :

Directly related to the application of Gauss's Law is the method of images (or image charges), which could be used to compute analytically some important problems by means of ready-made solutions, thus eliminating the need for formal solutions of Laplace's or Poisson's equations in differential form.

The image charge theory and the CSM are based on the uniqueness theorem which states that a solution V(x,y,z) to a problem consisting of a charge distribution $\rho(x,y,z)$ and grounded conducting boundaries S_1 through S_n, is the unique solution if it satisfies the differential equation

$$\nabla^2 V = -\rho(x,y,z)/\varepsilon$$

and the boundary conditions

$$V(x,y,z) = 0 \quad \text{on } S_1, S_2, \ldots, S_n \quad [5]$$

The principle of uniqueness can be applied to replace the effect of conducting boundaries with image charges. Some of the important cases are presented in the following. These cases are :

1. point charge and a grounded conducting plate (or say Earth) of semi-infinite dimensions.
2. point charge and a grounded conducting sphere.
3. point charge and a sphere at voltage V.
4. a line charge and a conducting cylinder at voltage V.
5. Two conducting cylinders at voltage +V and -V respectively.
6. A conducting cylinder at voltage V and a grounded conducting plate (or earth surface).
7. Two conducting spheres at voltages +V and -V respectively.
8. A conducting sphere at voltage +V and a grounded conducting plate (or earth surface); and similar few other cases.

Now the thesis discusses each of the above cases one by one. Significance of this lies in the fact that analytical methods are used to determine the location as well as the value of charges accurately. In CSM location is generally assumed (surely with certain optimization criteria) and the charge values are determined numerically.

Case 1 : Point charge and grounded conducting plate (or say Earth) of Semi-infinite dimension (Fig. 1).

Here the plate forms an equipotential surface at Voltage = 0. Thus, this plate can be replaced by a charge equal in magnitude and opposite in polarity placed symmetrically on the other side of the plate as shown in Fig. 1.

Thus voltage at any point P(r,z) would simply be

$$V(r,z) = KQ \left[\frac{1}{\sqrt{r^2+(Z-a)^2}} - \frac{1}{\sqrt{r^2+(Z+a)^2}} \right]$$

and Electric field components would be

$$E_r = \frac{-\partial V}{\partial r} = -2KQr \left[\frac{1}{\sqrt{r^2+(Z-a)^2}} - \frac{1}{\sqrt{r^2+(Z+a)^2}} \right]$$

and

$$E_z = \frac{-\partial V}{\partial z} = -2KQr \left[\frac{(z-a)}{r^2+(z-a)^2} - \frac{(z+a)}{r^2+(z+a)^2} \right]$$

Case 2 : Point charge and a grounded conducting sphere (Fig. 2)

Let the image charge of q be placed at x_o and let it's magnitude be q'. Now potential at any point (x,y,z) on the sphere is

$$V(x,y,z) = 0 = \frac{Kq}{\sqrt{(x-x_o)^2+y^2+z^2}} - \frac{Kq'}{\sqrt{(x-x_o)+y^2+z^2}}$$

or $q^2((x-x_o)^2+y^2+z^2) = q'^2((x-b)^2+y^2+z^2)$

i.e.

$$q^2(x-x_o)^2-q'^2(x-b)^2+(q^2-q'^2)y^2+(q^2-q'^2)z^2 = 0$$

i.e.

$$(q^2-q'^2)(x^2+y^2+z^2) = 2xx_oq^2 - 2xbq'^2 + b^2q'^2 - x_o^2q^2$$

Comparing with $x^2+y^2+z^2 = a^2$ we get

$$x_oq^2 - bq'^2 = 0 \rightarrow x_o = \frac{bq'^2}{q^2} \qquad (i)$$

and

$$\frac{b^2q'^2 - x_o^2q^2}{q^2 - q'^2} = a^2$$

i.e.

$$b^2q'^2 - x_o^2qq^2 = a^2q^2 - a^2q'^2 \qquad (ii)$$

$$\rightarrow (b^2+a^2)\, q'^2 = (a^2+x_o^2)\, q^2$$

Therefore,

$$b^2q'^2 - \left[\frac{bq'^2}{q^2}\right] \cdot q^2 = a^2q^2 - a^2q'^2$$

$$b^2q'^2 - \frac{b^2q'^4}{q^2} = a^2q^2 - a^2q'^2$$

$$b^2q'^2\left(1 - \frac{q'^2}{q^2}\right) = a^2(q^2 - q'^2)$$

$$= a^2q^2(1 - q'^2/q^2)$$

$$\rightarrow b^2q'^2 = a^2q^2$$

$$\rightarrow q' = \frac{a}{b}\,q \quad \rightarrow \quad x_o = \frac{a^2}{b}$$

Thus the grounded conducting sphere can be replaced by a image charge q', placed at a distance x_o from the centre.

The potential at any point (x,y,z) outside the sphere would be

$$V(x,y,z) = Kq\left[\frac{1}{\sqrt{(x-b)^2+y^2+z^2}}\right] - Kq'\left[\frac{1}{\sqrt{(x-x_o)^2+y^2+z^2}}\right]$$

$$K^{-1} = 4\Pi\varepsilon_o$$

and $\underline{E} = -\nabla \underline{V}$ which can also be calculated.

Case III : Point charge and a sphere at voltage V

In this case apart from the image chage q' placed at x_o, one more charge $Q_o = 4\Pi\varepsilon_o V$ is placed which gives a voltage V on the sphere surface.

Thus voltage and electric field at any point outside the sphere can be calculated as

$$V(x,y,z) = \frac{Kq}{\sqrt{(x-b)^2+y^2+z^2}} - \frac{Kq'}{\sqrt{(x-x_o)^2+y^2+z^2}} + \frac{KQ_o}{\sqrt{x^2+y^2+z^2}}$$

$$\underline{E} = -\nabla \underline{V}$$

Case IV, Case V & Case VI [6] :

A line charge and a cylinder at voltage V (Fig. 3) or two parallel cylinders at voltage +ve and -ve, respectively.

Consider a line charge ρ_1 running parallel to a conducting cylinder of radius R and carrying a charge $Q_1 = -\rho_1$ per unit length. The cross-section of the system is shown in Fig. 4. If the electric field of charges induced on the surface of the cylinder can be reduced to the field of a certain image line charge ρ_1', by symmetry the image line charge ρ_1' must be somewhere in the plane of the line charge ρ_1 and the axis of the cylinder, as indicated in Fig.4. The magnitude of the

charge ρ_1' and its position x with respect to the cylinder axis are unknown. If possible, we must determine these so that the surface of the cylinder is equipotential.

Now, according to Gauss' law, the total charge enclosed by a cylinder coinciding with the conductor surface equals the flux of the electric field intensity through the cylinder , multiplied by ε_o. If the field is assumed to be identical in the real case and that, when the cylinder is removed and the image line charge introduced instead, the flux of the electric field intensity is also the same, it follows that ρ_1', that is to $-\rho_1'$ must be equal to Q_1, that is to $-\rho_1$, as indicated in Fig.4.

The potential at a point M' at a distance r from a line charge ρ_1, with respect to a reference point at a distance r_R from the line charge, is

$$V = \int_r^{rR} \frac{\rho_1}{2\Pi\varepsilon_o r}\, dr = \frac{\rho_1}{2\Pi\varepsilon_o} \ln \frac{r_R}{r} \quad . \qquad (i)$$

The distance r_R cannot be taken to be infinite, since in this case there are charges at infinity. If we denote by r_R' and r' the corresponding from the line charge $\rho_1' = -\rho_1$, then the potential at the same point due to ρ_1' is

$$V' = \frac{\rho_1'}{2\Pi\varepsilon_o} \ln \frac{r_R'}{r'} = - \frac{\rho_1}{2\Pi\varepsilon_o} \ln \frac{r_R'}{r'} \quad .$$

So the total potential at M' is

$$V_{total} = V+V' = \frac{\rho_l}{2\pi\varepsilon_o}\left[\ln\frac{r_R}{r} - \ln\frac{r'_R}{r'}\right] = \frac{\rho_l}{2\pi\varepsilon_o}\ln\left[\frac{r_R}{r'_R}\frac{r'}{r}\right]$$

(ii)

From (ii) it is clear that the equation of any equipotential surface due to the two equal line charges of opposite signs is r'/r = constant. Hence, if the distance x of the image line charge ρ_l' from the axis of the cylinder can be determined so that r'/r = constant for all points on the surface of the cylinder, the image line charge is completely determined.

From Fig. 4, if triangles OM'P and OP'M' are similar (if x is chosen appropriately, this can always be the case for a fixed point M') then

$$r'/r = R/b = x/R$$

[b stands for (x+d), that is, for the distance from the line charge ρ_l to the cylinder axis.] Thus, equation r'/r = constant can be satisfied for any point on the cylinder surface is

$$x = R^2/b.$$

The Program 1 calculates for various points along the line joining the centres of the cylinder. The ratio of electric field at that point to the max field using image charge method.

Case VII & Case VIII : Two conducting spheres/A conducting sphere infront of a grounded conducting plate (See Fig.4) [5].

Some fields may be determined by the method of images through successive approximations. As an illustration the case of a charged sphere near a grounded plane has been considered. Both the spheres and the plane have been replaced by a set of point charges which will maintain these surfaces as equipotentials.

First a charge Q_o is put at the centre of the sphere, as in Fig. 6. This makes the sphere, but not the plane, an equipotential. Next we put the image $-Q_o$ of Q_o to the right of the plane. This makes the plane an equipotential but destroys the spherical equipotential, so we put the image Q_1 of $-Q_o$ inside the sphere. This makes the sphere again an equipotential but upsets the plane. We continue the process, which converges rapidly, until we have the required precision.

The maximum field strength at the points M and M' is given by

$$E_{max} = \frac{1}{4\Pi\varepsilon_o} \left\{ \sum_{n=o}^{\infty} \frac{Q_n}{(a-x_n)^2} + \sum_{n=o}^{\infty} \frac{Q_n}{(2D-a-x_n)^2} \right\}$$

where

$$Q_n = Q_{n-1} \left(\frac{R}{2D - x_{n-1}} \right)$$

and $$x_n = \frac{a^2}{(2D - x_{n-1})} \qquad \text{with } n = 1, 2, 3 \ldots$$

and $x_o = 0.$

Above equations are used to calculate the field intensities between two oppositely charged metal spheres along a field line of highest field strength, i.e. between the shortest distance M-M'.

Numerical calculation of image charges has been used for above case and the error in voltage at the tip obtained by numerical technique is extremely small for a fairly large number of charges.

In case of sphere and a plate, another hypothetical sphere is assumed to be placed symmetrically on the other side of the plate for the simulation purpose.

1.2 CSM Theory [1] :

CSM as mentioned above is the numerical counterpart of the image charge method which is an analytical method. CSM for field estimation is generally applied for complex electrode configurations which cannot be easily solved analytically using methods such as the Gausse's Law or the above mentioned image charges method.

The basic principle of CSM is very easy to formulate. Using the superposition principle, the potential functions of the fields of individual charges of any type (point, line or ring charges, for instance) can be found by a summation of the potentials (scalars) resulting from the individual charges. Let Q_j be a number n of individual charges, and ϕ_i be the potential at any point within the space (independent of the coordinate system used). The superposition principle results in

$$\phi_i = \sum_{j=1}^{n} p_{ij} Q_j \qquad (i)$$

where p_{ij} are the potential coefficients, which are known for many types of individual charges by particular solutions of Laplace's or Poisson's equations mentioned earlier.

Whereas the potential coefficients $p_{ij}, \ldots$ are known, only additional boundary conditions enable us to relate ϕ_i with Q_j quantitatively. If the individual charges are placed outside the space in which the field is to be computed (or inside of a closed metal electrode, whose surface is an equipotential, the magnitude of these charges are related to the distributed surface charges which are physically bonded by the electric flux leaving or entering the surface of any electrode or conductor surrounding these charges. If n charges Q_j are assumed, we require also at least n known potentials to solve

eqn.(i) for the priori unknown charge magnitudes. This can easily be done by identifying the potentials ϕ_i with n potentials on the surface of the conductors ("contour points"), which are adequately placed at a given electrode configuration. If this potential is $\phi_i = \phi_c$, we may rewrite eqn. (i) as

$$\sum_{j=1}^{n} p_{ij} Q_j = \phi_c \ . \qquad \text{(ii)}$$

This equation leads to a system of n linear equations for the n unknown charges

$$\begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & & & \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{bmatrix} \begin{Bmatrix} Q_1 \\ Q_2 \\ \vdots \\ Q_n \end{Bmatrix} = \begin{Bmatrix} \phi_1 \\ \phi_2 \\ \vdots \\ \phi_n \end{Bmatrix} \qquad \text{(iii)}$$

$$[p]\{Q\} = \{\phi\}.$$

After this system has been solved, it is necessary to check whether the set of calculated charges fits the actual boundary conditions. It must be emphasized that only n discrete contour points of the real electrode system have been used to solve eqn. (ii) and thus the potentials at any other contour points considered in this calculation might still be

different from ϕ_c. Therefore, eqn. (i) must be additionally used to compute the potentials at a number of "check points" located on the electrode boundary (with known potential). The difference between these potentials and the given boundary potential is then a measure of the accuracy and applicability of the simulation. The development and introduction of special objective functions in thus an important procedure within the optimization of the CSM.

As soon as an adequate charge system has been adopted the potentials and the field strength within the space can be computed. Whereas the potentials are found by superposition, i.e. by eqn. (i) or the corresponding set of linear equations [compare with eqn. (ii)], the field stresses are calculated by superposition of magnitudes and directional components. For a cartesian coordinate system for resistance, the x-coordinate E_x would then be for a number of n charges.

$$E_x = \sum_{j=1}^{n} \frac{\partial p_{ij}}{\partial x} Q_j = \sum_{j=1}^{n} (f_{ij})_x Q_j \qquad \text{(iv)}$$

where f_{ij} are "field intensity coefficients" in the x-direction.

1.3 Steps involved in CSM Programming

This CSM programming normally involves the following steps:

Step 1 : Assumptions about the type and number of charges to be used i.e. point, line and/or ring charges and proper location of these charges within the electrode surface.

Step 2 : Choice of representative points i.e. "contour points" on the surface of the electrode.

Step 3 : Calculation of potential-coefficients 'p_{ij}'.

Step 4 : Inversion of potential-matrix and multiplication with the voltage vector of the representative point to calculate the charge vector.

Step 5 : Choice of "check point" on the electrode surface for the calculation of voltage at these points to find out the deviation from the actual voltage.

Step 6 : Location optimization based on certain objective criteria.

Step 7 : Choice of one of the methods for calculation of equipotential lines.

Discussion about above steps :

Step 1 : In making assumptions regarding the type of charges to be used, one has to see the types of electrode surfaces to be reproduced or represented. Generally ring charges are suitable for reproducing spherical surfaces and line charges for cylindrical surfaces while point charges are appropriate for various types of surfaces as shown in Fig. 5. The complexity of computation, in general, increases with the complexity of the simulation charges used. This is because the potential coefficients become more difficult to compute numerically.

Step 2 : The "contour points" should be so chosen such that they fully take into account the critical points on the surfaces such as curves and corners etc. Larger number of contour points should be taken near such critical points.

Step 3 : Calculation of potential coefficients involves knowledge of analytical expression for voltages due to various discrete charges such as point, line and ring charges. Potential coefficients for certain discrete charges have been given in the following [1].

For Point Charges (Fig. 6)

$$P_{ij} = \frac{1}{4\pi\varepsilon\sqrt{r_i^2 + (z_i - z_j)^2}} \quad \text{in } (r,z) \text{ coordinate system}$$

where $(0,z_j)$ is the location of the point charge and (r_i,z_i) is the 'contour point'.

This expressions for field stress components become.

$$E_r = \sum_{j=1}^{n} \frac{+Q_j}{4\pi\varepsilon} \frac{r_i}{[r_i^2 + (z_i - z_j)^2]^{3/2}}$$

$$E_z = \sum_{j=1}^{n} \frac{Q_j}{4\pi\varepsilon} \frac{(z_i - z_j)}{[r_i^2 + (z_i - z_j)^2]^{3/2}}$$

For straight line charge (Fig. 7)

$$P_{ij} = \frac{1}{4\pi\varepsilon(z_{j2} - z_{j1})} \ln \left[\frac{(z_{j2} - z_i + \gamma_1)}{(z_{j1} - z_i + \delta_1)} \cdot \frac{(z_{j1} + z_i + \gamma_2)}{(z_{j2} + z_i + \delta_2)} \right]$$

$$\gamma_1 = \sqrt{\gamma_i^2 + (z_{j2} - z_i)^2}$$

$$\gamma_2 = \sqrt{\gamma_i^2 + (z_{j1} - z_i)^2}$$

$$\delta_1 = \sqrt{\gamma_i^2 + (z_{j1} - z_i)^2}$$

$$\delta_2 = \sqrt{\gamma_i^2 + (z_{j2} - z_i)^2}$$

And the electric field components become

$$E_r = \sum_{j=1}^{n} \frac{Q_j}{4\pi\varepsilon(z_{j2}-z_{j1})} \left[\frac{z_{j2}-z_i}{r_i\gamma_1} - \frac{z_{j1}-z_i}{r_i\delta_1} + \frac{z_{j1}+z_i}{r_i\gamma_2} - \frac{z_{j2}+z_i}{r_i\delta_2} \right]$$

and

$$E_z = \sum_{j=1}^{n} \frac{Q_j}{4\pi\varepsilon(z_{j2}-z_{j1})} \left[\frac{1}{\gamma_1} - \frac{1}{\delta_1} - \frac{1}{\gamma_2} + \frac{1}{\delta_2} \right]$$

For Ring Charges (Fig. 8)

$$P_{ij} = \frac{1}{4\pi\varepsilon} \cdot \frac{2}{\pi} \left[\frac{E(k_1)}{\alpha_1} - \frac{E(k_2)}{\alpha_2} \right]$$

where

$$\alpha_1 = \sqrt{(r_i+r_j)^2 + (z_i-z_j)^2}$$

$$\alpha_2 = \sqrt{(r_i+r_j)^2 + (z_i-z_j)^2}$$

$$\beta_1 = \sqrt{(r_i+r_j)^2 + (z_i-z_j)^2}$$

$$\beta_2 = \sqrt{(r_i+r_j)^2 + (z_i-z_j)^2}$$

and

$$k_1 = \frac{2\sqrt{r_i r_j}}{\alpha_1}, \quad k_2 = \frac{2\sqrt{r_i r_j}}{\alpha_2}$$

where E(k) is the complete elliptic integral of the first kind.

The field stress components become

$$E_r = \sum_{j=1}^{n} \frac{-Q_j}{4\pi\varepsilon} \frac{1}{\pi r_i} \left\{ \frac{[r_j^2 - r_i^2 + (z_i - z_j)^2]\, K(k_1) - \beta_1^2\, E(k_1)}{\alpha_1 \beta_1^2} \right.$$

$$\left. - \frac{r_j^2 - r_i^2 + (z_i + z_j)^2]\, K(k_1) - \beta_2^2\, E(k_2)}{\alpha_2 \beta_2^2} \right\}$$

and

$$E_z = \sum_{j=1}^{n} \frac{-Q_j}{r\pi\varepsilon} \frac{2}{\pi} \left\{ \frac{(z_i - z)\, K(k_1)}{\alpha_1 \beta_1^2} + \frac{(z_i + z_j)\, K(k_2)}{\alpha_2 \beta_2^2} \right\}$$

where K(k) is the complete elliptic integral of second kind.

Step 4 : "Check points" should be such as to correctly reflect the errors. The error is likely to be largest somewhere near middle of two "contour points". This assumption becomes more and more valid if the contour points are sufficiently close. If this is not so, then one can choose more than one point between two contour points for the calculation of error.

Step 5 : Error calculated at the check points can be used for the optimization of location of discrete charges within the electrode surface. One can also use some other objective

function for error minimisation. Greater is the accuracy required, greater is the requirement of error minimization. One such objective function is the cummulative square error at the "check points".

i.e. optimization of $U = \sum_j (V - \phi_j)^2$

For HV electrodes location-optimization.may be carried out by simply hit and trial method. But optimization becomes necessary in EHV electrodes where slightest deviation means meaningful errors.

One can also assign different weightages to the errors at various points on the electrode, i.e. more weightage to crucial points and less to unimportant points by minization of

$$U = \sum_j C_j (V - \phi_j)^2$$

where C_j's are the weightage coefficients.

In this work objective function used is the accumulated squared error of the electrostatic potential at the electrode surface. This objective function is suitable if the field gradient distribution between the electrode configuration is

the aim of the computation. On the other hand this optimization criterion may lead to greater errors if the field gradient at the electrode surface is the main aim of the calculation (Fig. 9).

In general the optimization variables, which are primarily the position of the charges and their values, are subject to the following equality and inequality constraints.

$$f(x_i) = A;\ f(x_i) \leq B;\ f(x_i) \leq C;\ D \leq f(x_i) \leq E$$

where $f(x_i)$ can be any one of the variables x_i, or, a linear or non-linear expression involving a number of variables (e.g., $x_1 + x_2 + 5x_3 = F$). A, B, C, D and F are constants related to the physical system.

The final consideration is the choice of the optimization technique or algorithm. The technique must be capable of handling highly nonlinear objective functions, equality and inequality constraints, and constraints that are described by linear or non-linear functions of the variables. Furthermore, it should be possible to change the constraints or the objective functions without modifying the optmization algorithm.

The availability of the first and second derivatives of the objective function U, determines whether or not gradient techniques that require these derivatives are suitable for use. A number of optimization subroutines are available in the FORTRAN and WATFIV scientific subroutine manuals. Rosenbrock's method is one of the earliest and most reliable technique, but has a relatively slow rate of convergence. One of the fast-converging techniques is Davidson's method as modified by Fletcher and Powell, combined with the Created Response Surface Technique of Carroll [2].

Other optimization algorithm generally used is given by Fletcher which is currently considered as one of the most powerful techniques for unconstrained optimization. This algorithm has the advantage of rapid convergence by a skillful use of the gradient g (where $g = \bar{\nabla}U$ with U being the objective function). It has been an additional advantage due to the fact that as the gradient g is computed, the electric field intensity $\vec{E}$ $(= -\bar{\nabla}\phi)$ on the desired boundary is implicitly computed. Therefore it can be achieved without any extra computation. This is a very desirable property especially for the applications in high voltage engineering [2].

This method of optimized simulated charges usually gives surprisingly good accuracy in capacitance calculations. The accuracy in potential and electric fields is relatively not as

good. The accuracy in field calculations deteriorates when corners and edges are encountered [2].

The computation time depends mainly on the rate of convergence of the optimization method used to minimize the objective function. Fast converging techniques should be used if computer time is an important parameter. Other factors that could influence the computation time are the initial values of the optimization parameters and the effectiveness of the objective function [2].

The error minimization can either be done in an open loop by hit and trial method, or in a closed loop whereby the computer itself decides the location of the simulation charges for obtaining minimum error.

Step 6 : Calculation of equipotential surfaces

Several methods of plotting equipotential surfaces have been considered.

Method I : By finding out potentials at several points in the space around the electrode and thenjoining thepoints of the same potentials. But this would require very large number of calculations as the number of points would be very large. it would also

involve problems for plotting. Hence this method is considered impractical.

Method II: Other method could be to derive an equation for equipotential surfaces and plot these equations using computer. But in this case due to large number of charges involved the equation of equipotential surfaces is not explicit in one of the variables (r or z). Hence it cannot be plotted using digital computers using methods such as Newton-Raphson etc. which are applicable only in case of explicit equations.

Method III: In this method we exploit the fact that the electrode surface itself is an equipotential surface. Also, we keep z constant i.e. we first find points on one line parallel to the r-axis and repeat the process along several such lines.

Let us consider an electrode surface as shown in Fig. 10. Consider points a,b,c,d on the elctrode surface. Their potential = V_r. Therefore, potential at infinitsimal distance dr from the electrode surface = V_{r+dr}.

We know from Taylor's series expansion that,

$$V_{r+dr} = V_r + \left.\frac{\partial V_r}{\partial r}\right|_{(r,z)} dr$$

If we take $V_{r+dr} = V_r - xV_r$ i.e. smaller by xV_r, then

$$V_r - xV_r = V_r + \left(\partial V_r/\partial r\right)_{r,z} \cdot dr$$

$$\rightarrow \quad dr = \left[-xV_r / \left(\partial V_r/\partial r\right)_{r,z}\right]$$

Thus knowing s, V_r and $(\partial V/\partial r)_{x,z}$, dr can be found out, i.e. the distance in which the voltage would drop by some given factor x.

The new r value considered is $r_{initial}+(dr)_r$ and the z value remains the same.

Now we apply this to several points on the electrode surface and join the new points obtained as shown. This process can again be repeated at a', b', c', d' and further new points can be found out. Thus the equipotential surfaces can be plotted.

Method IV: It is known that potential along an equipotential surface is constant.

Also $V = f(r,z)$

$$dV = (\partial f/\partial r)\, dr + (\partial f/\partial z)$$

Along an equipotential $dV = 0$

$$\left(\frac{dz}{dr}\right) = \frac{-(\partial f/\partial r)}{+(\partial f/\partial z)}$$

or

$$dz = -\left[(\partial f/\partial r)/(\partial f/\partial z)\right] dr$$

$$= -\left(E_r/E_z\right)_{r,z} dr \qquad \text{Since} \begin{cases} -\partial f/\partial r = E_r \\ \text{and} \\ -\partial f/\partial z = E_z \end{cases}$$

where E_r and E_z are electric field component at (r,z). By taking dr = constant value (small), we can find dz by calculating Electric field components at (r,z). The new point is given by (r+dr, z+dz). Thus starting from a fixed point (r_o, z_o) the entire equipotential surface can be found passing through that point.

However, this method has one limitation. It cannot be applied to those problems where the equipotential surface is

expected to be vertical or of negative slope at some place for example in rod-plane and sphere-sphere case; because (dr) being fixed, any small step dr from such an equipotential would push the calculations out of that particular equipotential surface. This method has been used only for the 'Rogowski-electrodes' case and the rod-rod case.

Method V : The method described below is devoid of any limitations of earlier methods.

An element dL along the equipotential surface can be written as

$$(dL)^2 = (dr)^2 + (dz)^2$$

or

$$\frac{(dL)^2}{(dz)^2} = \left[1 + (dr/dz)^2\right]$$

or $$dL/dz = \pm \sqrt{1 + (dr/dz)^2}$$

or $$dz = \frac{\pm\, dL}{\sqrt{1 + (dr/dz)^2}}$$

Since $$(dz/dr) = -(E_r/E_z) \qquad \text{(i)}$$

Therefore

$$dz = \frac{\pm\, dL}{\sqrt{1 + (E_z/E_r)^2}} \qquad \text{(ii)}$$

Thus,by taking (dL) to have a very small constant value, the equipotential surfaces can be calculated by using equations (i) and (ii) . At the tip of the electrode, E_r is equal to zero. This may give overflow error in case of equation (ii) when using digital computer. Thus, care should be taken to incorporate additional statements in the programme to avoid this. dz has two possible values. Correspondingly, dr also has two values. Thus correct value of dz should be determined by storing the previous point in the programme. In case of monotonically rising equipotentials, dz would always be +ve. This method has been used in the sphere-sphere case and multidielectric case.

CHAPTER 2

SAMPLE PROBLEMS FOR CSM APPLICATION TO CONFIGURATIONS INVOLVING SINGLE DIELECTRIC

1. **Problem 1 :** A conducting cylinder/conductor running parallel to the ground. The image charge theory gives the location and value of charge to be used. This has been converted into a program with certain additional features.

   Prog. 1 : This program asks the person running the program to give the number of charges N as input. It calculates the location and value of the charges given by the image-theory. It also calculates the error at the tip of the sphere.

2. **Problem 2 :** Two spherical electrodes of opposite polarity have been taken to show the rapid fall in error with increase in the number of image-charges as shown in Fig. 16.

   Prog. 2 : The program asks the radius and voltage of the cylindrical conductor. It also asks for the distance of centre of the sphere fromthe zero potential line. It then calculates the position and value of image charge using image theory. It also calculates the ratio $F = (E/E_{max})$ at large number of points from conductor tip to the ground.

3. **Problem 3 :** Two spherical electrodes with three charges have been taken and CSM applied. Further, equipotential surfaces have been plotted to check the accuracy of CSM as shown in Fig. 12.

As seen earlier, atleast three charges are required for minimizing the error. Though the location points could be chosen at the image points, but in order to show that the error does not increase substantially even if charges are located at some other points; the charges were placed equidistant along the axis i.e. at 0.15, 0.2 and 0.25 m. (for a sphere of 0.1 m. radius).

Two contour points have been taken at the tips of the diameter along the axis of sphere and one at right angle to this diameter on the sphere surface i.e. at (0.0, 0.1), (0.0, 0.3), (0.1, 0.2). This has been done so that the entire sphere can be given a good representation and to minimize the error.

Test points have been chosen on the entire sphere surface, 15° apart from each other and error has been calculated on these points with voltage of the sphere assumed to be 1 V.

Prog. 3 : This program asks for the charge location inside the spherical electrodes and the contour location of points. It also asks for the radius of the sphere and the distance of its centre from zero potential surface. The program then calculates

(a) Simulation Charge values.

(b) errors on the electrode surface at points 15° apart covering the electrode.

(c) the cummulative square error.

(d) Equipotential surfaces.

4. Two spherical tip-shaped rods of opposite polarity are considered. CSM has been applied using line and point charges. Accuracy is then checked by plotting the equpotential surfaces in the region of interest as shown in Fig. 14.

Spherical part of the rod can be best represented by considering a point charge placed at the centre while the cylindrical part can be represented by line charges most appropriately. Now one can choose line charges of equal length, progressively decreasing length or progressively increasing length. To decide this, error reduction process was resorted. It was accompanied with successive variation of parameters such as, length of first line charge and multiplying factor for the length of line charges. In this way only one parameter was changed at a time while the

others were kept constant. The result which gave the minimum error for a radius of unit length was

length of first line charge = 0.1

mulyiplying factor A1 = 0.6

This is not to suggest that these are the optimum values but they are only one of the several possible sets of values for low error. Since the multiplying factor is less than 1, therefore, the line charges are of progressively decreasing length. Here 9 line charges were considered.

Prog. 4 : This program asks for the radius of the spherical part of the electrodes and also the distance of it's centre from the zero-potential surface. It also asks for the length of first line segment (l) and the multiplying factor (A1) for successive 8 other line segments. The program itself then calculates the contour points, some of them on the spherical part and others on the cylindrical part. It then calculates the value of point and the line charges and their location. It also calculates the equipotential surfaces.

5. **Problem 5 :** Rogowski-Profiled electrode has been taken and equipotential electrode surfaces for different gap spacings plotted. Ring-charges have been considered for this program as shown in Fig. 17.

CHAPTER 3

THE MULTIDIELECTRIC CASE

For a field space containing only one dielectric material, the application of the CSM to three-dimensional problems does not present fundamental difficulties. Even unsymmetrical electrode configurations can be treated by means of discrete charges [1].

In contrast to the simple solutions within the FDM or FEM for treating multidielectric cases, the CSM when used for field calculations in systems composed of two or more dielectrics increases the cost. This may be understood by considering the fundamental mathematical solutions and the physical mechanisms involved. The CSM is directly based upon physical charges and in every dielectric material polarization processes take place. Whereas in a homogeneous material placed between electrodes the absolute value of its permittivity does not contribute to the field strength (or potentials), but only the flux density D, the field distribution at the boundaries of different materials is heavily distorted due to the dipole charges at the boundaries which may not have counterparts at the adjacent medium. The law of dielectric refraction results from the physical effect and is associated with an infinitely thin layer of bonded charges located in the two media. The

free surface charges physically present due to electrical condition of the interface also contribute to field distortions, but the common dielectric refraction is not related to such additional charges.

This realignment of dipoles within different dielectric materials must therefore be considered within the CSM. An exact solution with CSM must be based upon the physical dipole surface charge density. But continuous surfaces can also be simulated by discrete charges by replacing the surface charge density to metal electrode. This method, originally presented by P. Weiss, will be presented briefly through a simple example [1].

Figure 12 displays a cross-section of a part of an insulation system, in which a metal electrode with fixed potential, $\phi = \phi_c$, meets two adjoining dielectric materials I and II. The actual shapes of the two-dimensional surfaces of the three different boundaries (electrode-dielectric I, electrode-dielectric II, dielectric I-dielectric II) determine the optimal types of discrete charges simulating the problem. Thus, the localized charges 1-7 will represent point charges as well as intersections with line or ring charges. From earl'ier considerations it is obvious that a part of the charges (nos. 1-3 denoted as n_E) have been placed inside the elctrode, i.e. behind the metal surface. However, the same is

true for the charges placed on both sides of the dielectric interface (nos. 4-7), beccause the influence of the dipolar charges within dielectric I upon the field in dielectric II can be simulated by the discrete charges nos. 4 and 5 within dielectric I and vice versa. A limited number of contour points placed at a ϕ = constant boundary is necessary, which is equal to the number of simulated charges within an electrode, and thus a number (n_E = 3) contour points (nos. 1-3) are adequate. For the dielectric interface, however, it will be sufficient for this example to place only two contour points corresponding to the two pairs of simulation charges (nos. 4 and 6, nos. 5 and 7), as each contour point belongs to dielectric I as well as to dielectric II. Equal number of charges, designated by n_B, on both sides of the dielectric interface are thus convenient and they should be placed at positions uniformly distributed between the mutual contour points and adjacent charges respectively. For our example, n_B is equal to 2 only.

Now it is possible to set up a system of equations for our unknown charges based upon well-known boundary conditions. These boundary conditions can be subdivided into three parts as follows :

(1) The electrode-dielectric interface is a boundary with known potential, $\phi = \phi_c$. The absolute magnitude of the surface charge density at this electrode is dependent upon the relative permittivity ε_r of the dielectric materials due to the polarization mechanisms in both dielectric materials. Since $D = \varepsilon E = \varepsilon_r \varepsilon_o E$, where ε_o is the permittivity of vacuum, the absolute magnitudes of our simulation charges would depend upon these material characteristic parameters. It is necessary to take these physical effects into account, which are included within the potenial coefficents. For any homogeneous dielectric material, the electric field may be computed independent of relative permittivity ε_r, and the potential coefficients are in general always computed by assuming $\varepsilon=\varepsilon_o$. The absolute magnitudes of the discrete charges used within our system are based upon a superposition of potentials. And thus we can use the known potential at the electrode interface to derive two sets of equations based upon n_E contour points taking only dielectric I into account, for which the charges within dielectric II can be neglected :

$$\sum_{j=1}^{n_E} Q_j P_{ij} + \sum_{j=n_E+1}^{n_E+n_B} Q_j P_{ij} = \phi_c \qquad \text{(i)}$$

(1-3) (4-5)

Using eqns. (iii) and (iv) subject to two new boundary conditions, the electric field within dielectric II could be

computed. All Q_j charges within eqn.(i), which are not yet known, define the potentials within this material.

For the computation of the field distribution within dielectric I, the same considerations are applicable. But now we neglect the charges within dielectric I, which resultsin an equal set of three or n_E equations,

$$\sum_{j=1}^{n_E} Q_j P_{ij} + \sum_{j=n_E+n_B+1}^{n_E+2n_B} Q_j P_{ij} = \phi_c \qquad \text{(ii)}$$

(1-3) (6-7)

(2) The potential at the dielectric interface is unknown. We know, that due to the continuity of the potential at either side of the interface, the potentials must be equal at each contour point. As the charges within the electrode (nos. 1-3) will not disturb the continuity condition, the potentials due to the charges within the dielectric materials must satisfy the condition.

$$\sum_{j=1}^{n_E} Q_j P_{ij} + \sum_{j=n_E+n_B+1}^{n_E+2n_B} Q_j P_{ij} = \phi_c \qquad \text{(iii)}$$

(4-5) (6-7)

This equation refers to a number of n_B (=2) contour points, giving an equal number of new equations. In these equations charges Q_j are involved, which have not yet been used within eqn. (i) or eqn. (ii) respectively. It should be noticed that this potential continuity condition implies that the field stress components tangential to the interface are equal.

3. Finally, the third boundary condition refers to the continuity of the normal component of the electric flux density crossing the dielectric interface or the discontinuity of the normal components of the field intensity. To include this condition, the "field intensity coefficient" f_{ij} must be considered, which is the contribution of the charge j to that component of the field vector, which is normal to the dielectric boundary at a contour point i. Then for any normal component $(E_n)_i = Q_j f_{ij}$, this condition may be written as

$$\varepsilon_I \left[\underbrace{\sum_{j=1}^{n_E} Q_j f_{ij}}_{(1-3)} + \underbrace{\sum_{j=n_E+n_B+1}^{n_E+2n_B} Q_j f_{ij}}_{(6-7)} \right] =$$

$$\varepsilon_{II} \left[\underbrace{\sum_{j=1}^{n_E} Q_j f_{ij}}_{(1-3)} + \underbrace{\sum_{j=n_E+1}^{n_E+n_B} Q_j f_{ij}}_{(4-5)} \right] \qquad \text{(iv)}$$

where ε_I and ε_{II} are the permittivities of the two dielectrics. This equation refers again to a number of n_B contour points, and thus a total number of (n_E+2n_B) linear equations are given for the calculations of the same number of unknown charges. This procedure demonstrates the difficulties involved with the implementation of dielectric boundaries, as a significant number of additional charges increase the computational efforts.

CHAPTER 4

PROGRAMMING FOR THE MULTIDIELECTRIC CASE

This program is quite different from the preceeding programs because of the presence of surface charges on the dielectric. Essential details of the program are given below :

(a) Charge locations : The program involves three sets of charge locations. First, those simulation charges which are inside the electrode; second, those simulation charges which are in the air near the air dielectric interface; third, those which are inside the dielectric near the air dielectric interface.

(b) Contour points : There are three sets of contour points. First, those on the electrode air interface; second, those on the electrode dielectric interface; third, those on the air dielectric interface.

(c) Potential matrix : The potential matrix has coefficient arising out of the following reasons :

(i) due to potential on the air electrode interface.

(ii) due to potential on the electrode dielectric interface.

(iii) due to equating of potentials on the air dielectric interface.

(iv) due to equating of vertical components of the electric field on the air dielectric interface with

the relative permittivity taken into account.

(d) **Matrix inversion and multiplication with a vector of 1's and 0's at appropriate positions.**

(e) **Error calculations** : Calculates the error at desired points on the electrode surface.

(f) **Equipotential surface calculation** : Calculates the equipotential surface passing through a desired initial point in air or dielectric.

(g) **Tangential field calculation** : Calculates the tangential field at the desired points on the interface between air and dielectric.

The program asks for the various charge location, contour points on the electrode, the coefficients of the two boundaries, the relative permittivity of the dielectric with respect to air, the points on the electrode surface where error calculations are desired, the points on the interface where tangential field calculations are desired, the backup and the initial point of the equipotential surface.

The above programme has been run for a sample problem namely a spherical electrode of radius = 10 cm., with its centre 20 cm. above a dielectric block of height 10 cm. and width 20 cm. as shown in Fig. 19.

The equipotential surfaces plotted by using the programme have been shown in Fig. 20.

CONCLUSION

(a) In practice, the appropriate shaping of electrode configurations within insulation systems is an essential task, as field stresses may well be reduced and kept low by this method. Such electrode shape optimization techniques are either based upon an iterative process in which the contour points are shifted after each computation of the field stresses or are based upon a superposition of fixed simulation charges representing the original system and additional "optimization" charges by which the field distribution gets changed due to a given objective function [1].

(b) The application of discrete simulation charges used in the charge simulation technique provide at least a very reliable and efficient method to solve many two- and three-dimensional problems. However, it should be recognized that the option of surface charges at electrodes or dielectric boundaries, i.e. distributed layers of charge sources in free space, offers definite advantages, because in this simultation method the role of physical charges, which are the origin of electric flux densities, is taken directly into account.

The main contributions made in this thesis are as follows:

(a) CSM has been presented in a unified manner. Evolution of CSM from image field theory has been successfully presented.

(b) The thesis has presented successful programs for parallel conductors, sphere-sphere and rod-plane electrode configurations involving single dielectrics.

(c) Important basics for further work on CSM have been developed namely the mathematical theory for plotting the equipotential. The missing links in the theory of multielectric case with rotational symmetry have been brought out and the problem of programming the multielectric case has been successfully developed. The problem of incorporating the vertical components of field on any arbitrarily inclined interface and from any arbitrarily placed charges has also been solved in the program. Apart from this the program has also solved the problem of equipotential surface plotting at the interface and the proper choice of sign of dz.

SUGGESTED WORK

(1) The program on Multidielectric case which this thesis has presented involves only point charges inside as well as outsidethe electrode surface. The program can be further extended to include line and ring charges within the electrode surface also.

(2) The program is valid for axially symmetric cases. Programs involving electrode with non-axial symmetry can also be developed.

(3) The charge location has essentially been done by hit and trial method which is an open loop programming process. For higher accuracy it is important to adopt closed loop method of error minimization which will have to be incorporated into the program.

(4) The charge location optimization criteria used in this program is the cummulative square error. Some better methods can be used as suggested in Chapter 2 in this thesis.

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APPENDIX

The realization of homogeneous fields within a finite volume of insulating material is very difficult. Using parallel metal plates of limited dimensions creates the problem of a proper stress control at the edges of the plates. The field problem becomes thus three-dimensional, though a rotational symmetry exists if the parallel plates are circular discs.

Depending upon the material to be tested, the breakdown strength may be very sensitive to local high fields within the whole electrode arrangement. Therefore, the highest stress should only be present in the homogeneous field region, where the plates are in parallel. A certain profile of the electrodes is necessary outside the plane region to limit the dimensions, but the field strength at the curved edges should never exceed the value E = V/d, if V is the applied voltage and d the distance between the parallel plates. Rogowski proposed electrodes for uniform fields for axially symmetrical systems whose profile follows the analytical function first introduced by Maxwell,

$$z = \frac{a}{\pi} (w + 1 + e^{w}) \qquad (a)$$

where z and w represent the complex coordinates in the z- and w-planes. Substitution of the coordinates for the complex

values $z = x+iy$ and $w = u+iv$ and separation of the real and imaginary parts gives

$$x = \frac{a}{\pi}(u + 1 + e^{u} \cos v);$$

$$y = \frac{a}{\pi}(v + e^{u} \sin v). \qquad (b)$$

Assuming two infinite, parallel "plates" in the w-plane, the coordinates of which are given by $v = \pm\pi = \text{const}$, it can be recognized from eqn. (b) that these plates are transformed into the z-plane to the left half-plane only. All other lines $v = \text{const}$ with $-\pi < v < +\pi$ can be assumed to be other equipotential lines, and all lines $u = \text{const}$ with $-\infty \leq u \leq +\infty$ can be assumed to be field lines in the w-plane, representing a uniform field distribution. These lines appear in the z-plane as shown in Fig. (a) providing the electrical field distribution of parallel plates terminating at $x = 0$. The concentration of the equipotential lines, $v = \text{const}$, within the z-plane may well be recognized at, or in the vicinity of, the edges of the plates.

The parallel plates, $v = \pm\pi$, are thus inadequate to fulfill the demand for field distribution whose intensity is limited to the field strength within the homogeneous part of the arrangement, i.e.for $u \lesssim -\pi$. It is obvious that the field strength along equipotential lines for which $-\pi < v < +\pi$ provide better conditions. For quantitative assessment the

field strength within the z-plane may be computed in several ways, as shown :

From the conjugate complex field strength in the z-plane

$$E_z^* = E_x - iE_y = i\frac{dw}{dz} = i\frac{1}{\frac{dz}{dw}} \qquad (c)$$

the absolute values could be computed by $|E_z^*| = \sqrt{E^2 + E^2}$

A second possibility is given by

$$E_z = E_x + iE_y = -\text{grad } v = -\left[\left(\frac{\partial v}{\partial x}\right) + i\left(\frac{\partial v}{\partial y}\right)\right] \qquad (d)$$

which needs a partial differentiation only.

Finally, the absolute value of E_z may be computed by

$$|E_z| = \frac{1}{\sqrt{(\frac{\partial x}{\partial v})^2 + (\frac{\partial y}{\partial v})^2}}, \qquad (e)$$

a method which is easiest to apply to our separated analytical function, eqn. (b). Combining eqns. (b) and (e), we easily may find the field strength as

$$|E_z| = \frac{\pi}{a\sqrt{1+e^{2u}+2e^u \cos v}} = f(u;v)$$

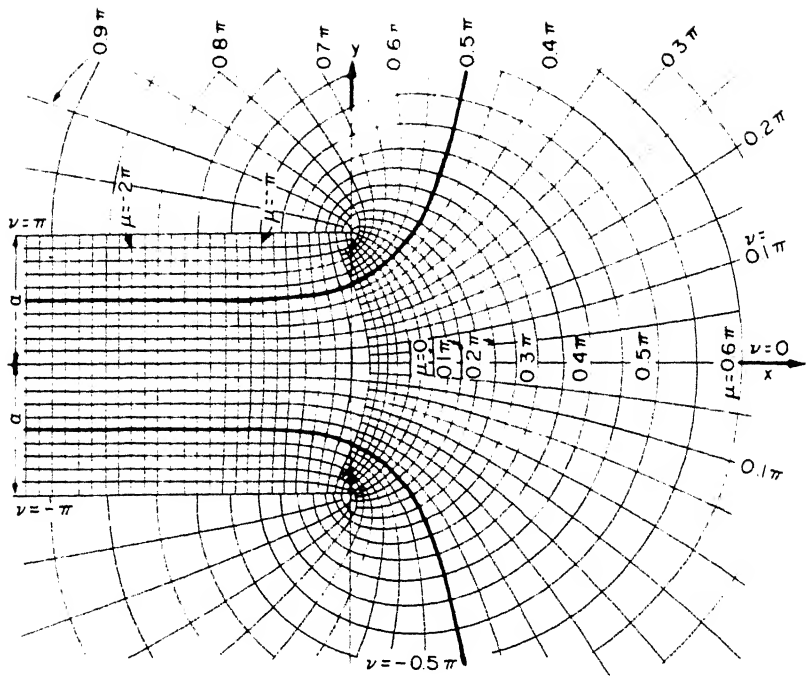

FIG. A · Transformation of a square grid from a w-plane in the displayed z-plane by eqn (A) Rogowski's profile ($\nu = \pm\pi/2$).

PROGRAMMES

```
PROGRAM PARCYL;
CONST K=18.0E09;
VAR Z1,V,ZC,R,ZO,Z,L,PO,EM,VZ,EZ,F,DZ:REAL;
U,I:INTEGER;



F1,F2:TEXT;
BEGIN
ASSIGN(F1,'PAR.PRN');
REWRITE(F1);
WRITELN('VOLTAGE,CENTRE,RADIUS ARE');
READLN(V,ZC,R);
WRITELN(F1,'VOLTAGE OF THE CYLINDER=',V:8:4);
WRITELN(F1,'DISTANCE OF CENTRE FROM THE PLATE=',ZC:8:4);
WRITELN(F1,'RADIUS=',R:8:4);
WRITELN;
ZO:=SQRT(SQR(ZC)-SQR(R));
WRITELN(F1,'LOCATION OF LINE CHARGE FROM THE PLATE=',ZO:8:4);
Z1:=(ZC-R);
L:=LN((ZO+Z1)/(ZO-Z1));
PO:=V/(K*L);
WRITELN(F1,'CHARGE PER UNIT LENGTH =',PO);
WRITELN(F1,'==========================================================');
WRITELN('NUMBER OF POINTS BETWEEN CYLINDER AND PLATE =');
READLN(U);
WRITELN(F1,'NUMBER OF POINTS BETWEEN CYLINDER AND PLATE= ',U);
DZ:=(ZC-R)/U;
EM:=K*po*((1/(ZO-ZC+R))-(1/(ZO+ZC-R)));
WRITELN(F1);
WRITELN(F1,'MAXIMUM FIELD INTENSITY =',EM:8:4);
WRITELN(F1);
FOR I:=0 TO U DO
BEGIN
z:=I*DZ;
WRITELN (F1,'Z=',Z:8:4);
VZ:=K*PO*(LN(ZO+Z)-LN(ZO-Z));
WRITELN(F1,'VOLTAGE AT Z=',VZ:8:4);
EZ:=K*PO*((1/(ZO-Z))-(1/(ZO+Z)));
WRITELN(F1,'ELECTRIC FIELD AT Z=',EZ:8:4);
f:=EZ/EM;
WRITELN(F1,'F AT Z=',F:8:8);
WRITELN(F1)
END;
END.
```

```
VOLTAGE OF THE CYLINDER=10000.0000
DISTANCE OF CENTRE FROM THE PLATE=  0.2000
RADIUS=  0.1000
LOCATION OF LINE CHARGE FROM THE PLATE=  0.1732
CHARGE PER UNIT LENGTH = 4.2184762083E-07
============================================================
NUMBER OF POINTS BETWEEN CYLINDER AND PLATE= 20

MAXIMUM FIELD INTENSITY =75932.5718

Z=  0.0000
VOLTAGE AT Z=  0.0000
ELECTRIC FIELD AT Z=  0.0000
F AT Z=0.00000000

Z=  0.0050
VOLTAGE AT Z=438.5187
ELECTRIC FIELD AT Z=2533.1967
F AT Z=0.03336113

Z=  0.0100
VOLTAGE AT Z=877.7700
ELECTRIC FIELD AT Z=5079.1018
F AT Z=0.06688963

Z=  0.0150
VOLTAGE AT Z=1318.4936
ELECTRIC FIELD AT Z=7650.6370
F AT Z=0.10075567

Z=  0.0200
VOLTAGE AT Z=1761.4443
ELECTRIC FIELD AT Z=10261.1583
F AT Z=0.13513514

Z=  0.0250
VOLTAGE AT Z=2207.3998
ELECTRIC FIELD AT Z=12924.6931
F AT Z=0.17021277

Z=  0.0300
VOLTAGE AT Z=2657.1691
ELECTRIC FIELD AT Z=15656.2004
F AT Z=0.20618557

Z=  0.0350
VOLTAGE AT Z=3111.6020
ELECTRIC FIELD AT Z=18471.8680
F AT Z=0.24326672

Z=  0.0400
VOLTAGE AT Z=3571.5995
ELECTRIC FIELD AT Z=21389.4568
F AT Z=0.28169014

Z=  0.0450
VOLTAGE AT Z=4038.1259
```

```
ELECTRIC FIELD AT Z=24428.7094
F AT Z=0.32171582

Z=  0.0500
VOLTAGE AT Z=4512.2225
ELECTRIC FIELD AT Z=27611.8443
F AT Z=0.36363636

Z=  0.0550
VOLTAGE AT Z=4995.0239
ELECTRIC FIELD AT Z=30964.1627
F AT Z=0.40778499

Z=  0.0600
VOLTAGE AT Z=5487.7775
ELECTRIC FIELD AT Z=34514.8053
F AT Z=0.45454545

Z=  0.0650
VOLTAGE AT Z=5991.8671
ELECTRIC FIELD AT Z=38297.7084
F AT Z=0.50436469

Z=  0.0700
VOLTAGE AT Z=6508.8410
ELECTRIC FIELD AT Z=42352.8289
F AT Z=0.55776892

Z=  0.0750
VOLTAGE AT Z=7040.4482
ELECTRIC FIELD AT Z=46727.7365
F AT Z=0.61538462

Z=  0.0800
VOLTAGE AT Z=7588.6824
ELECTRIC FIELD AT Z=51479.7097
F AT Z=0.67796610

Z=  0.0850
VOLTAGE AT Z=8155.8385
ELECTRIC FIELD AT Z=56678.5387
F AT Z=0.74643249

Z=  0.0900
VOLTAGE AT Z=8744.5855
ELECTRIC FIELD AT Z=62410.3329
F AT Z=0.82191781

Z=  0.0950
VOLTAGE AT Z=9358.0615
ELECTRIC FIELD AT Z=68782.7825
F AT Z=0.90584029

Z=  0.1000
VOLTAGE AT Z=10000.0000
```

```
PROGRAM SSERIES;
uses crt;
CONST K=9.0E09;
pi=3.1419;
VAR B,V,R,Q0,Q1,XNI,QNI,QT,EI,XNF,QNF,C,X1,V0,V1,VT,EROR:REAL;
ch:char;
N,I:INTEGER;
F1,F2:TEXT;
BEGIN
ASSIGN(F1,'SS.PRN');
REWRITE(F1);
clrscr;
writeln('Give the distance between the centres of spheres');
READLN(B);
writeln('Give the voltage of the spheres');
READLN(V);
writeln('Give the value of Radius of the spheres');
READLN(R);
writeln('==================================');
WRITELN(f1,' Distance between the centres of sphere= ',B:12:6);
writeln(f1,' Voltage of the sphere= ',V:12:6);
writeln(f1,' Radius of the sphere= ',R:14:6);
writeln(f1,'==================================');
writeln(f1);
writeln('Press any key to Continue');

ch:=readkey;
writeln('Give the no of Charges');
READLN(N);
WRITELN(F1,'NUMBER OF CHARGES=',N);
Q0:=R*V/K;
WRITELN(F1,'Q0=',Q0);
V0:=V-(K*Q0/(B-R));
WRITELN(F1);
X1:=SQR(R)/B;
WRITELN(F1,'X1=',X1);
Q1:=Q0*R/B;
WRITELN(F1,'Q1=',Q1);
V1:=K*Q1*((1/(R-X1))-(1/(B-X1-R)));
XNI:=X1;
QNI:=Q1;
WRITELN(F1);



QT:=Q0+Q1;
VT:=V0+V1;
EI:=K*((Q0/SQR(R))-(Q0/SQR(B-R))+(Q1/SQR(R-X1))-(Q1/SQR(B-R-X1)));
FOR I:=2 TO N DO
BEGIN
XNF:=SQR(R)/(B-XNI);
WRITELN(F1,'X=',XNF);
QNF:=QNI*R/(B-XNI);
WRITELN(F1,'Q=',QNF);
VT:=VT+K*QNF*((1/(R-XNF))-(1/(B-XNF-R)));
QT:=QT+QNF;
EI:=EI+K*((QNF/SQR(R-XNF))-(QNF/sqr(B-R-XNF)));
xni:=xnf;
qni:=qnf;
WRITELN(F1)
END;
WRITELN(f1,'TOTAL CHARGE ON SPHERE=',QT);
WRITELN(F1,'ELECTRIC FIELD AT THE TIP=',EI);
C:=QT*0.5/V;
WRITELN(F1,'CAPACITANCE=',C);
EROR:=((V-VT)/V)*100;
WRITELN(F1,'ERROR AT THE TIP=',EROR);
CLOSE(F1)
END.
```

```
 Distance between the centres of sphere=      0.400000
 Voltage of the sphere= 10000.000000
 Radius of the sphere=        0.100000
==================================

NUMBER OF CHARGES=10
Q0= 1.1111111111E-07

X1= 2.5000000000E-02
Q1= 2.7777777778E-08

X= 2.6666666667E-02
Q= 7.4074074074E-09

X= 2.6785714286E-02
Q= 1.9841269841E-09

X= 2.6794258373E-02
Q= 5.3163211057E-10

X= 2.6794871795E-02
Q= 1.4245014245E-10




X= 2.6794915836E-02
Q= 3.8169395778E-11

X= 2.6794918998E-02
Q= 1.0227458681E-11

X= 2.6794919225E-02
Q= 2.7404392924E-12

X= 2.6794919242E-02
Q= 7.3429849526E-13

X= 2.6794919243E-02
Q= 1.9675468881E-13

TOTAL CHARGE ON SPHERE= 1.4900657388E-07
ELECTRIC FIELD AT THE TIP= 1.4575598322E+05
CAPACITANCE= 7.4503286939E-12
ERROR AT THE TIP= 6.4816325903E-05
```

```
PROGRAM MATCOFF;
CONST N=3; m=1;
type mat=array [1..n,1..n] of real;
     cat=array [1..n,1..2] of real;
     rat=array [1..n,1..m] of real;
VAR RZ:cat;
PQ:cat;
charge:rat;
NST:mat;
ZC,R,PJ,QJ,VI,VJ,DH,DL,RI,ZI,THETA,ER,EZ,DZ,DR,EROR,ERROR,A,B,C,D:REAL;
   L1,I1,J1,THETAJ,THETAO,V1,VM,G,U1:INTEGER;

NST1,NST2:REAL;
I,J,K,L,S,u,v,T:INTEGER;
F1,F2,F3:TEXT;
procedure inverse(a:mat; VAR  b:rat);
CONST NM=50;
      N=3; M=1;
VAR  IPIV:ARRAY[1..NM] OF INTEGER;
    INDXR:ARRAY[1..NM] OF INTEGER;
    INDXC:ARRAY[1..NM] OF INTEGER;
    BIG,DUM,PIVINV:REAL;
    I,J,V,U,LL,K,L,P,Q,ICOL,IROW:INTEGER;

BEGIN
{ FOR P:=1 TO N DO
  BEGIN
   FOR Q:=1 TO N DO
    BEGIN
```

```
    READ(A[P,Q]);
    END;
    READLN
    END;}
  FOR P:=1 TO N DO
   BEGIN
    FOR Q:=1 TO M DO
     BEGIN
     B[P,Q]:=1.0;
     END;
    END;
 FOR J:=1 TO N DO
   BEGIN
    IPIV[J]:=0;
   END;
  FOR I:=1 TO N DO
   BEGIN
    BIG:=0.0;
    FOR J:=1 TO N DO
     BEGIN
      IF (IPIV[J]<>1) THEN
       BEGIN
        FOR K:=1 TO N DO
        BEGIN
         IF (IPIV[K]=0) THEN
          BEGIN
           IF (ABS(A[J,K]))=BIG) THEN
            BEGIN
             BIG:=ABS(A[J,K]);
             IROW:=J;
             ICOL:=K
            END;
            END
            ELSE
            IF (IPIV[K])1 ) THEN
             BEGIN
              WRITELN('SINGULAR POINT');
              READLN
            END;
          END
       END
       END;
       IPIV[ICOL]:=IPIV[ICOL]+1;
       IF (IROW <> ICOL) THEN
        BEGIN
         FOR L:=1 TO N DO
         BEGIN
          DUM:=A[IROW,L];
          A[IROW,L]:=A[ICOL,L];
          A[ICOL,L]:=DUM
         END;
         FOR L:=1 TO M DO
          BEGIN
           DUM:=B[IROW,L];
           B[IROW,L]:=B[ICOL,L];
           B[ICOL,L]:=DUM
          END;
        END;
        INDXR[I]:=IROW;
        INDXR[I]:=ICOL;
        IF (A[ICOL,ICOL]=0.0) THEN
         BEGIN
          WRITELN('SING MATRIX') ;
          READLN
        END;
```

```
        PIVINV:=(1.0/A[ICOL,ICOL]);
        A[ICOL,ICOL]:=1.0;
        FOR L:=1 TO N DO
         BEGIN
          A[ICOL,L]:=A[ICOL,L]*PIVINV
         END;
       FOR L:=1 TO M DO
       BEGIN
        B[ICOL,L]:=B[ICOL,L]*PIVINV
       END;
       FOR LL:=1 TO N  DO
         BEGIN
          IF (LL<>ICOL) THEN
          BEGIN
           DUM:=A[LL,ICOL];
           A[LL,ICOL]:=0.0;
           FOR L:=1 TO N DO
            BEGIN
             A[LL,L]:=A[LL,L]-A[ICOL,L]*DUM;
            END;
            FOR L:=1 TO M DO
            BEGIN
             B[LL,L]:=B[LL,L]-B[ICOL,L]*DUM
            END;
          END;
         END;
        END;
        FOR L:=N DOWNTO  1  DO
         BEGIN
           IF (INDXR[L]<>INDXC[L]) THEN
            BEGIN
            FOR K:=1 TO N DO
            BEGIN
             DUM:=A[K ,INDXR[L]];
             A[K,INDXR[L]]:=A[K,INDXC[L]];
             A[K,INDXC[L]]:=DUM
            END;
         END;
        END;
          { FOR U:=1 TO N DO
           BEGIN
            FOR V:=1 TO M DO
             BEGIN
              WRITE(B[U,V]:8:3)
             END;
             WRITELN
           END;}
        END;
(=====================END OF PROCEDURE INVERSE ============================)
BEGIN
ASSIGN(F1,'S31.PRN');
REWRITE(F1);
WRITELN('TEST POINTS ');
WRITELN(F1,'TEST POINTS ');
FOR I:=1 TO N DO
BEGIN
FOR J:=1 TO 2 DO
BEGIN
READ(PQ[I,J]);
WRITE(F1,PQ[I,J]:8:4);
END;
READLN;
WRITELN(F1);
WRITELN(F1)
END;
READLN;
```

```
----------------------------------------------------');
:E LOCATIONS ARE ');
(ARGE LOCATIONS ARE ');
 DO

 DO

;
,L]:8:4);




==================================================');
ISTANCE MATRIX IS');
 DO

 DO

(SQR(PQ[S,1]-RZ[T,1])+SQR(PQ[S,2]-RZ[T,2])));
(SQR(PQ[S,1]-RZ[T,1])+SQR(PQ[S,2]+RZ[T,2])));
1-NST2;
S,T]:8:4);
);


***CALLING THE  PROCEDURE  INVERSE  ***********************)
charge);
==========================================================');
harge vector is');
 do

 do

arge[u,1]:12:8)


==========================================================');
==================ERROR CALCULATION====================)
 CENTRE  & RADIUS ARE ');
],' CENTRE  & RADIUS ARE ');
,R);
], 'CENTRE=',ZC:8:4,'  RADIUS=',R:8:4);
5;
)IV THETAO);
;
]);
1,'-----------------------------------------');
 TO (VM+1) DO

V1-1)*THETAO;
'THETA=',THETAJ:8);
THETA=',THETAJ:8);
(THETAJ*3.142/180);
COS(THETAJ*3.142/180);
'PJ=',PJ);
1,'QJ=',QJ);

 TO N DO

E[L1,1]*((1/SQRT(SQR(RZ[L1,1]-PJ)+SQR(RZ[L1,2]-QJ)))-(1/SQRT(SQR(RZ[L1,1]+PJ)+SQR(RZ[L1,2]+QJ))))
```

```
    WRITELN(F1,'VOLTAGE AT POINT PJ,QJ IS',VJ:8:4);
    EROR:=(1-VJ);
    ERROR:=ERROR+SQR(EROR);
    WRITEln(F1,'ERROR AT PJ,QJ=',EROR:8:4);
    WRITELN(F1,'-----------------------------------------------')
    END;
    WRITELN(F1);
    WRITELN(F1,'CUMMULATIVE SQUARE ERROR=',ERROR:8:8) ;
    WRITELN(F1);
writeln(F1);
writeln(F1,'==============================================================');
writeln(F1,'==============equipotential surface calculation==============');
DH:=(ZC-R)/5;
DL:=R/7.5;
FOR G:=1 TO 5 DO
BEGIN
RI:=0.0005;
ZI:=(G)*DH;
WRITELN(F1,'RI=',RI:8:4,'  ZI=',ZI:8:4);
WRITELN(F1,'-----------------------------------------');
WHILE RI>0.0  DO
BEGIN
ER:=0.0;
EZ:=0.0;
FOR U1:=1 TO N DO
BEGIN
A:=(1/(SQR(RZ[U1,1]-RI)+SQR(RZ[U1,2]-ZI)));
B:=(1/(SQR(RZ[U1,1]-RI)+SQR(RZ[U1,2]+ZI)));
ER:=ER+CHARGE[U1,1]*2*(A-B);
C:=((ZI-RZ[U1,2])/(SQR(RI-RZ[U1,1])+SQR(ZI-RZ[U1,2])));
D:=((ZI+RZ[U1,2])/(SQR(RI-RZ[U1,1])+SQR(ZI+RZ[U1,2])));
EZ:=EZ+2*CHARGE[U1,1]*(C-D);
END;
WRITELN(F1,'ER=',ER:12:4,'  EZ=',EZ:12:4);
WRITELN(F1,'-----------------------------------------------------------');
IF ER=0.0 THEN
BEGIN
DZ:=0.0;
DR:=DL
END
ELSE
BEGIN
DZ:=DL/SQRT(1+SQR(EZ/ER));
DR:=-(EZ/ER)*DZ
END;
ZI:=ZI+DZ;
RI:=RI+DR;
WRITELN(F1,'RI=',RI:8:4,'  ZI=',ZI:8:4);
writeln('-----------------------------------------------------------');
END;
WRITELN(F1);
WRITELN (F1)
END;
WRITELN(F1,'==========================================================')
END.
```

```
TEST POINTS
  0.0000  0.1000

  0.1000  0.2000

  0.0000  0.3000

------------------------------------------------------------
CHARGE LOCATIONS ARE
  0.0000  0.1500

  0.0000  0.2000

  0.0000  0.2500

============================================================
DISTANCE MATRIX IS
 16.0000    6.6667    3.8095
  6.1971    7.5746    6.7750
  4.4444    8.0000   18.1818
============================================================
charge vector is
  0.01074476
  0.12595306
 -0.00304584

============================================================
 CENTRE  & RADIUS ARE
CENTRE=  0.2000  RADIUS=  0.1000

-------------------------------------------
THETA=       0PJ= 0.0000000000E+00QJ= 1.0000000000E-01
VOLTAGE AT POINT PJ,QJ IS  1.0000
ERROR AT PJ,QJ= -0.0000
-------------------------------------------------
THETA=      15PJ= 2.5885183382E-02QJ= 1.0340829600E-01
VOLTAGE AT POINT PJ,QJ IS  0.9935
ERROR AT PJ,QJ=  0.0065
```

```
------------------------------------------------
THETA=      30PJ= 5.0005879424E-02QJ= 1.1340085437E-01
VOLTAGE AT POINT PJ,QJ IS  0.9833
ERROR AT PJ,QJ=  0.0167
------------------------------------------------
THETA=      45PJ= 7.0717878687E-02QJ= 1.2929652318E-01
VOLTAGE AT POINT PJ,QJ IS  0.9802
ERROR AT PJ,QJ=  0.0198
------------------------------------------------
THETA=      60PJ= 8.6609328687E-02QJ= 1.5001175954E-01
VOLTAGE AT POINT PJ,QJ IS  0.9843
ERROR AT PJ,QJ=  0.0157
------------------------------------------------
THETA=      75PJ= 9.6596974113E-02QJ= 1.7413449030E-01
VOLTAGE AT POINT PJ,QJ IS  0.9919
ERROR AT PJ,QJ=  0.0081
------------------------------------------------
THETA=      90PJ= 9.9999997925E-02QJ= 2.0002036732E-01
VOLTAGE AT POINT PJ,QJ IS  1.0000
ERROR AT PJ,QJ= -0.0000
------------------------------------------------
THETA=     105PJ= 9.6586429876E-02QJ= 2.2590485599E-01
VOLTAGE AT POINT PJ,QJ IS  1.0066
ERROR AT PJ,QJ= -0.0066
------------------------------------------------
THETA=     120PJ= 8.6588958971E-02QJ= 2.5002351631E-01
VOLTAGE AT POINT PJ,QJ IS  1.0105
ERROR AT PJ,QJ= -0.0105
------------------------------------------------
THETA=     135PJ= 7.0689072013E-02QJ= 2.7073227762E-01
VOLTAGE AT POINT PJ,QJ IS  1.0110
ERROR AT PJ,QJ= -0.0110
------------------------------------------------
THETA=     150PJ= 4.9970599425E-02QJ= 2.8661950816E-01
VOLTAGE AT POINT PJ,QJ IS  1.0080
ERROR AT PJ,QJ= -0.0080
------------------------------------------------
THETA=     165PJ= 2.5845834952E-02QJ= 2.9660224022E-01
VOLTAGE AT POINT PJ,QJ IS  1.0028
ERROR AT PJ,QJ= -0.0028
------------------------------------------------
THETA=     180PJ=-4.0734639662E-05QJ= 2.9999999170E-01
VOLTAGE AT POINT PJ,QJ IS  1.0000
ERROR AT PJ,QJ= -0.0000
------------------------------------------------

CUMMULATIVE SQUARE ERROR=0.00136970


============================================================
==============equipotential surface calculation=============
RI=  0.0005  ZI=  0.0200
------------------------------------------
ER=      3.0666  EZ=     -2.7872
----------------------------------------------------------
RI=  0.0095  ZI=  0.0299
ER=      4.6862  EZ=     -2.8177
----------------------------------------------------------
RI=  0.0163  ZI=  0.0413
ER=      6.7173  EZ=     -2.8648
----------------------------------------------------------
RI=  0.0216  ZI=  0.0536
ER=      9.2044  EZ=     -2.9360
----------------------------------------------------------
RI=  0.0256  ZI=  0.0663
ER=     12.2973  EZ=     -3.0353
```

```
RI=  0.0288  ZI=  0.0792
ER=     16.2657  EZ=     -3.1655
-----------------------------------------------------------
RI=  0.0314  ZI=  0.0923
ER=     21.5402  EZ=     -3.3279
-----------------------------------------------------------
RI=  0.0334  ZI=  0.1055
ER=     28.7774  EZ=     -3.5186
-----------------------------------------------------------
RI=  0.0350  ZI=  0.1187
ER=     38.8662  EZ=     -3.7186
-----------------------------------------------------------
RI=  0.0363  ZI=  0.1320
ER=     52.5904  EZ=     -3.8807
-----------------------------------------------------------
RI=  0.0373  ZI=  0.1453
ER=     69.9061  EZ=     -3.9426
-----------------------------------------------------------
RI=  0.0380  ZI=  0.1586
ER=     91.1068  EZ=     -3.8710
-----------------------------------------------------------
RI=  0.0386  ZI=  0.1719
ER=    118.7264  EZ=     -3.5263
-----------------------------------------------------------
RI=  0.0390  ZI=  0.1852
ER=    149.8647  EZ=     -2.4939
-----------------------------------------------------------
RI=  0.0392  ZI=  0.1986
ER=    166.0374  EZ=     -0.5650
-----------------------------------------------------------
RI=  0.0392  ZI=  0.2119
ER=    150.1214  EZ=      1.4559
-----------------------------------------------------------
RI=  0.0391  ZI=  0.2252
ER=    114.8871  EZ=      2.5972
-----------------------------------------------------------
RI=  0.0388  ZI=  0.2386
ER=     81.3018  EZ=      2.8785
-----------------------------------------------------------
RI=  0.0383  ZI=  0.2519
ER=     56.8611  EZ=      2.7225
-----------------------------------------------------------
RI=  0.0377  ZI=  0.2652
ER=     40.9184  EZ=      2.4300
-----------------------------------------------------------
RI=  0.0369  ZI=  0.2785
ER=     30.6781  EZ=      2.1405
-----------------------------------------------------------
RI=  0.0360  ZI=  0.2918
ER=     23.7790  EZ=      1.8903
-----------------------------------------------------------
RI=  0.0349  ZI=  0.3051
ER=     18.8864  EZ=      1.6789
-----------------------------------------------------------
RI=  0.0338  ZI=  0.3184
ER=     15.2907  EZ=      1.5000
-----------------------------------------------------------
RI=  0.0325  ZI=  0.3317
ER=     12.5800  EZ=      1.3479
-----------------------------------------------------------
RI=  0.0310  ZI=  0.3449
ER=     10.4941  EZ=      1.2178
-----------------------------------------------------------
RI=  0.0295  ZI=  0.3582
ER=      8.8605  EZ=      1.1058
```

```
RI=  0.0278  ZI=  0.3714
ER=       7.5610  EZ=       1.0087
RI=  0.0261  ZI=  0.3846
ER=       6.5130  EZ=       0.9241
RI=  0.0242  ZI=  0.3978
ER=       5.6573  EZ=       0.8500
RI=  0.0222  ZI=  0.4110
ER=       4.9508  EZ=       0.7846
RI=  0.0201  ZI=  0.4242
ER=       4.3615  EZ=       0.7267
RI=  0.0179  ZI=  0.4373
ER=       3.8656  EZ=       0.6751
RI=  0.0157  ZI=  0.4505
ER=       3.4449  EZ=       0.6289
RI=  0.0133  ZI=  0.4636
ER=       3.0852  EZ=       0.5874
RI=  0.0108  ZI=  0.4767
ER=       2.7757  EZ=       0.5499
RI=  0.0082  ZI=  0.4897
ER=       2.5076  EZ=       0.5160
RI=  0.0055  ZI=  0.5028
ER=       2.2742  EZ=       0.4852
RI= .0.0027  ZI=  0.5158
ER=       2.0697  EZ=       0.4571
RI= -0.0002  ZI=  0.5289


RI=  0.0005  ZI=  0.0400
ER=       6.5816  EZ=      -2.8824
RI=  0.0058  ZI=  0.0522
ER=       9.1830  EZ=      -2.9743
RI=  0.0100  ZI=  0.0649
ER=      12.4886  EZ=      -3.1009
RI=  0.0132  ZI=  0.0778
ER=      16.8634  EZ=      -3.2715
RI=  0.0157  ZI=  0.0909
ER=      22.9731  EZ=      -3.4988
RI=  0.0177  ZI=  0.1041
ER=      32.0924  EZ=      -3.7992
RI=  0.0193  ZI=  0.1173
ER=      46.8322  EZ=      -4.1878
RI=  0.0205  ZI=  0.1306
ER=      72.2681  EZ=      -4.6341
RI=  0.0213  ZI=  0.1439
```

```
ER=     110.8825  EZ=      -4.9221
-------------------------------------------------------------
RI=   0.0219  ZI=   0.1573
ER=     146.6664  EZ=      -5.0689
-------------------------------------------------------------
RI=   0.0224  ZI=   0.1706
ER=     204.7403  EZ=      -5.6044
-------------------------------------------------------------
RI=   0.0227  ZI=   0.1839
ER=     334.3655  EZ=      -5.4069
-------------------------------------------------------------
RI=   0.0230  ZI=   0.1972
ER=     475.3594  EZ=      -1.5145
-------------------------------------------------------------
RI=   0.0230  ZI=   0.2106
ER=     393.6564  EZ=       3.9245
-------------------------------------------------------------
RI=   0.0229  ZI=   0.2239
ER=     227.1643  EZ=       5.2630
-------------------------------------------------------------
RI=   0.0226  ZI=   0.2372
ER=     125.0433  EZ=       4.6779
-------------------------------------------------------------
RI=   0.0221  ZI=   0.2506
ER=      70.9499  EZ=       3.7832
-------------------------------------------------------------
RI=   0.0214  ZI=   0.2639
ER=      46.4706  EZ=       3.0175
-------------------------------------------------------------
RI=   0.0205  ZI=   0.2772
ER=      34.3415  EZ=       2.5052
-------------------------------------------------------------
RI=   0.0195  ZI=   0.2905
ER=      26.3196  EZ=       2.1381
-------------------------------------------------------------
RI=   0.0184  ZI=   0.3038
ER=      20.6131  EZ=       1.8540
-------------------------------------------------------------
RI=   0.0172  ZI=   0.3170
ER=      16.4666  EZ=       1.6266
-------------------------------------------------------------
RI=   0.0159  ZI=   0.3303
ER=      13.3921  EZ=       1.4411
-------------------------------------------------------------
RI=   0.0145  ZI=   0.3436
ER=      11.0651  EZ=       1.2873
-------------------------------------------------------------
RI=   0.0130  ZI=   0.3568
ER=       9.2691  EZ=       1.1583
-------------------------------------------------------------
RI=   0.0113  ZI=   0.3700
ER=       7.8583  EZ=       1.0487
-------------------------------------------------------------
RI=   0.0095  ZI=   0.3833
ER=       6.7324  EZ=       0.9549
-------------------------------------------------------------
RI=   0.0077  ZI=   0.3965
ER=       5.8212  EZ=       0.8737
-------------------------------------------------------------
RI=   0.0057  ZI=   0.4097
ER=       5.0745  EZ=       0.8030
-------------------------------------------------------------
RI=   0.0036  ZI=   0.4228
ER=       4.4558  EZ=       0.7408
-------------------------------------------------------------
RI=   0.0014  ZI=   0.4360
```

```
ER=       3.9379  EZ=       0.6860
-----------------------------------------------------------
RI= -0.0009  ZI=  0.4491


RI=  0.0005  ZI=  0.0600
-----------------------------------------
ER=      11.1861  EZ=      -3.0576
-----------------------------------------------------------
RI=  0.0040  ZI=  0.0729
ER=      15.2196  EZ=      -3.2234
-----------------------------------------------------------
RI=  0.0068  ZI=  0.0859
ER=      20.8187  EZ=      -3.4481
-----------------------------------------------------------
RI=  0.0090  ZI=  0.0991
ER=      29.1868  EZ=      -3.7554
-----------------------------------------------------------
RI=  0.0107  ZI=  0.1123
ER=      43.0886  EZ=      -4.1844
-----------------------------------------------------------
RI=  0.0119  ZI=  0.1256
ER=      70.3377  EZ=      -4.7943
-----------------------------------------------------------
RI=  0.0129  ZI=  0.1389
ER=     135.8978  EZ=      -5.5199
-----------------------------------------------------------
RI=  0.0134  ZI=  0.1522
ER=     215.9730  EZ=      -5.3392
-----------------------------------------------------------
RI=  0.0137  ZI=  0.1655
ER=     230.0174  EZ=      -6.1994
-----------------------------------------------------------
RI=  0.0141  ZI=  0.1788
ER=     407.6140  EZ=      -8.2807
-----------------------------------------------------------
RI=  0.0144  ZI=  0.1922
ER=     949.4174  EZ=      -7.5129
-----------------------------------------------------------
RI=  0.0145  ZI=  0.2055
ER=    1054.5332  EZ=       5.6085
-----------------------------------------------------------
RI=  0.0144  ZI=  0.2188
ER=     446.0281  EZ=       8.2598
-----------------------------------------------------------
RI=  0.0141  ZI=  0.2322
ER=     193.9043  EZ=       6.4009
-----------------------------------------------------------
RI=  0.0137  ZI=  0.2455
ER=      83.2542  EZ=       4.8225
-----------------------------------------------------------
RI=  0.0129  ZI=  0.2588
ER=      45.0874  EZ=       3.4728
-----------------------------------------------------------
RI=  0.0119  ZI=  0.2721
ER=      37.7078  EZ=       2.7895
-----------------------------------------------------------
RI=  0.0109  ZI=  0.2854
ER=      29.5534  EZ=       2.3463
-----------------------------------------------------------
RI=  0.0099  ZI=  0.2987
ER=      23.0106  EZ=       2.0094
-----------------------------------------------------------
RI=  0.0087  ZI=  0.3120
ER=      18.1916  EZ=       1.7446
-----------------------------------------------------------
```

```
ER=       3.9379  EZ=       0.6860
-----------------------------------------------------------
RI= -0.0009  ZI=  0.4491


RI=  0.0005  ZI=  0.0600
-----------------------------------------
ER=      11.1861  EZ=      -3.0576
-----------------------------------------------------------
RI=  0.0040  ZI=  0.0729
ER=      15.2196  EZ=      -3.2234
-----------------------------------------------------------
RI=  0.0068  ZI=  0.0859
ER=      20.8187  EZ=      -3.4481
-----------------------------------------------------------
RI=  0.0090  ZI=  0.0991
ER=      29.1868  EZ=      -3.7554
-----------------------------------------------------------
RI=  0.0107  ZI=  0.1123
ER=      43.0886  EZ=      -4.1844
-----------------------------------------------------------
RI=  0.0119  ZI=  0.1256
ER=      70.3377  EZ=      -4.7943
-----------------------------------------------------------
RI=  0.0129  ZI=  0.1389
ER=     135.8978  EZ=      -5.5199
-----------------------------------------------------------
RI=  0.0134  ZI=  0.1522
ER=     215.9730  EZ=      -5.3392
-----------------------------------------------------------
RI=  0.0137  ZI=  0.1655
ER=     230.0174  EZ=      -6.1994
-----------------------------------------------------------
RI=  0.0141  ZI=  0.1788
ER=     407.6140  EZ=      -8.2807
-----------------------------------------------------------
RI=  0.0144  ZI=  0.1922
ER=     949.4174  EZ=      -7.5129
-----------------------------------------------------------
RI=  0.0145  ZI=  0.2055
ER=    1054.5332  EZ=       5.6085
-----------------------------------------------------------
RI=  0.0144  ZI=  0.2188
ER=     446.0281  EZ=       8.2598
-----------------------------------------------------------
RI=  0.0141  ZI=  0.2322
ER=     193.9043  EZ=       6.4009
-----------------------------------------------------------
RI=  0.0137  ZI=  0.2455
ER=      83.2542  EZ=       4.8225
-----------------------------------------------------------
RI=  0.0129  ZI=  0.2588
ER=      45.0874  EZ=       3.4728
-----------------------------------------------------------
RI=  0.0119  ZI=  0.2721
ER=      37.7078  EZ=       2.7895
-----------------------------------------------------------
RI=  0.0109  ZI=  0.2854
ER=      29.5534  EZ=       2.3463
-----------------------------------------------------------
RI=  0.0099  ZI=  0.2987
ER=      23.0106  EZ=       2.0094
-----------------------------------------------------------
RI=  0.0087  ZI=  0.3120
ER=      18.1916  EZ=       1.7446
-----------------------------------------------------------
```

```
RI=  0.0074  ZI=  0.3252
ER=     14.6471  EZ=       1.5324
-------------------------------------------------------
RI=  0.0060  ZI=  0.3385
ER=     11.9961  EZ=       1.3594
-------------------------------------------------------
RI=  0.0045  ZI=  0.3517
ER=      9.9739  EZ=       1.2160
-------------------------------------------------------
RI=  0.0029  ZI=  0.3650
ER=      8.4019  EZ=       1.0957
-------------------------------------------------------
RI=  0.0012  ZI=  0.3782
ER=      7.1588  EZ=       0.9935
-------------------------------------------------------
RI= -0.0006  ZI=  0.3914


RI=  0.0005  ZI=  0.0800
---------------------------------------
ER=     18.1044  EZ=      -3.3450
-------------------------------------------------------
RI=  0.0029  ZI=  0.0931
ER=     25.1636  EZ=      -3.6229
-------------------------------------------------------
RI=  0.0048  ZI=  0.1063
ER=     36.4853  EZ=      -4.0141
-------------------------------------------------------
RI=  0.0063  ZI=  0.1196
ER=     57.8708  EZ=      -4.5945
-------------------------------------------------------
RI=  0.0073  ZI=  0.1329
ER=    114.0555  EZ=      -5.5314
-------------------------------------------------------
RI=  0.0080  ZI=  0.1462
ER=    356.4141  EZ=      -6.3551
-------------------------------------------------------
RI=  0.0082  ZI=  0.1595
ER=    280.7800  EZ=      -5.3687
-------------------------------------------------------
RI=  0.0085  ZI=  0.1728
ER=    344.2901  EZ=      -8.2726
-------------------------------------------------------
RI=  0.0088  ZI=  0.1862
ER=    949.3098  EZ=     -13.0141
-------------------------------------------------------
RI=  0.0090  ZI=  0.1995
ER=   3120.2399  EZ=      -1.7146
-------------------------------------------------------
RI=  0.0090  ZI=  0.2128
ER=   1026.5351  EZ=      13.0084
-------------------------------------------------------
RI=  0.0088  ZI=  0.2262
ER=    323.2616  EZ=       8.5153
-------------------------------------------------------
RI=  0.0085  ZI=  0.2395
ER=    122.2365  EZ=       6.0728
-------------------------------------------------------
RI=  0.0078  ZI=  0.2528
ER=      0.5017  EZ=       4.0303
-------------------------------------------------------
RI= -0.0054  ZI=  0.2545


RI=  0.0005  ZI=  0.1000
-----------------------------------------
```

```
ER=      30.4211  EZ=      -3.8164
-------------------------------------------------------------
RI=  0.0022  ZI=  0.1132
ER=      46.1193  EZ=      -4.3083
-------------------------------------------------------------
RI=  0.0034  ZI=  0.1265
ER=      81.6683  EZ=      -5.0998
-------------------------------------------------------------
RI=  0.0042  ZI=  0.1398
ER=     242.9013  EZ=      -6.7084
-------------------------------------------------------------
RI=  0.0046  ZI=  0.1531
ER=     803.6458  EZ=      -3.8545
-------------------------------------------------------------
RI=  0.0047  ZI=  0.1665
ER=     290.2484  EZ=      -6.8313
-------------------------------------------------------------
RI=  0.0050  ZI=  0.1798
ER=     602.6244  EZ=     -11.6852
-------------------------------------------------------------
RI=  0.0052  ZI=  0.1931
ER=    3387.1527  EZ=     -23.2938
-------------------------------------------------------------
RI=  0.0053  ZI=  0.2065
ER=    3590.1042  EZ=      23.0556
-------------------------------------------------------------
RI=  0.0052  ZI=  0.2198
ER=     596.7892  EZ=      11.7460
-------------------------------------------------------------
RI=  0.0050  ZI=  0.2331
ER=     206.3640  EZ=       7.4001
-------------------------------------------------------------
RI=  0.0045  ZI=  0.2465
ER=     -69.0556  EZ=       5.6461
-------------------------------------------------------------
RI=  0.0056  ZI=  0.2597
ER=      22.1685  EZ=       3.3163
-------------------------------------------------------------
RI=  0.0036  ZI=  0.2729
ER=      36.1367  EZ=       2.7892
-------------------------------------------------------------
RI=  0.0026  ZI=  0.2862
ER=      29.2333  EZ=       2.3533
-------------------------------------------------------------
RI=  0.0015  ZI=  0.2995
ER=      22.8136  EZ=       2.0105
                                                 -------------
```

```
PROGRAM RODPLANE;
USES CRT;
CONST N=10;
type
MATRIX1=ARRAY [1..N,1..N] OF REAL;
MATRIX2=ARRAY [1..N,1..1] OF REAL;

{=======================================================================}
PROCEDURE INVERSE(A:MATRIX1;   VAR  B:MATRIX2);
CONST NM=50;




N=10;
M=1;
VAR
INDXR:ARRAY[1..NM] OF INTEGER;
INDXC:ARRAY[1..NM] OF INTEGER;
IPIV:ARRAY[1..NM] OF INTEGER;
BIG,DUM,PIVINV:REAL;
I,J,V,U,LL,K,L,P,Q,ICOL,IROW:INTEGER;
BEGIN (OF PROCEDURE)
  FOR P:=1 TO N DO
   BEGIN
    FOR Q:=1 TO M DO
     BEGIN
     B[P,Q]:=1.0;
     END;
   END;
 FOR J:=1 TO N DO
   BEGIN
    IPIV[J]:=0;
   END;
  FOR I:=1 TO N DO
   BEGIN
    BIG:=0.0;
    FOR J:=1 TO N DO
     BEGIN
      IF (IPIV[J]<>1) THEN
       BEGIN
        FOR K:=1 TO N DO
        BEGIN
         IF (IPIV[K]=0) THEN
          BEGIN
           IF (ABS(A[J,K])>=BIG) THEN
            BEGIN
             BIG:=ABS(A[J,K]);
             IROW:=J;
             ICOL:=K
            END; END
            ELSE
            IF (IPIV[K]>1 ) THEN
             BEGIN
              WRITELN('SINGULAR POINT');
              READLN
            END;
          END
       END
     END;
      IPIV[ICOL]:=IPIV[ICOL]+1;
      IF (IROW <> ICOL) THEN
      BEGIN
       FOR L:=1 TO N DO
        BEGIN
          DUM:=A[IROW,L];
          A[IROW,L]:=A[ICOL,L];
          A[ICOL,L]:=DUM
        END;
         FOR L:=1 TO M DO
          BEGIN
           DUM:=B[IROW,L];
           B[IROW,L]:=B[ICOL,L];
           B[ICOL,L]:=DUM
          END;
      END;
        INDXR[I]:=IROW;
        INDXR[I]:=ICOL;
        IF (A[ICOL,ICOL]=0.0) THEN
         BEGIN
```

```
          WRITELN('********* IT IS A SINGULAR  MATRIX ********') ;
          READLN
         END;
         PIVINV:=(1.0/A[ICOL,ICOL]);
        A[ICOL,ICOL]:=1.0;
        FOR L:=1 TO N DO
         BEGIN
          A[ICOL,L]:=A[ICOL,L]*PIVINV
         END;
       FOR L:=1 TO M DO
       BEGIN
        B[ICOL,L]:=B[ICOL,L]*PIVINV
       END;
       FOR LL:=1 TO N  DO
         BEGIN
          IF (LL<>ICOL) THEN
          BEGIN
           DUM:=A[LL,ICOL];
           A[LL,ICOL]:=0.0;
           FOR L:=1 TO N DO
            BEGIN
             A[LL,L]:=A[LL,L]-A[ICOL,L]*DUM;
            END;
            FOR L:=1 TO M DO
            BEGIN
             B[LL,L]:=B[LL,L]-B[ICOL,L]*DUM
            END;
          END;
         END;
        FOR L:=N DOWNTO  1  DO
         BEGIN
           IF (INDXR[L]<>INDXC[L]) THEN
            BEGIN
            FOR K:=1 TO N DO
            BEGIN
             DUM:=A[K ,INDXR[L]];
             A[K,INDXR[L]]:=A[K,INDXC[L]];
             A[K,INDXC[L]]:=DUM
            END;
          END;
         END;
         WRITELN('================================================================');
      END;
{MAIN PROGRAMME
================
================)
CONST   M=20; {M)=N+6)   Q=10;{Q=M-N)
VAR ZN:ARRAY [1..N] OF REAL;       {END POINTS OF THE LINE ELEMENTS)
PQ:ARRAY [1..M,1..2] OF REAL;      {CONTOUR POINTS ,CHECK POINTS)
MAT:ARRAY [1..M,1..N] OF REAL;     {POTENTIAL COFFICIENTS)
CAT:MATRIX1;
CHARGE:MATRIX2;
VOL:ARRAY [1..Q] OF REAL;
DRI,elec,eror,R0,THETA,R,G,L,A1,D1,D2,ERROR,D21,D22,d11,d12,M1,M2,DH,DL,RI,ZI,ER,EZ:REAL;
E1,E2,G1,G2,DL1,DL2,F1,F2,F3,F4,DZ,DR:REAL;
O,P,B1,C,D,I,J,K,S,T,U,V,I1:INTEGER;
file1:text;
BEGIN
assign(file1,'san.prn');
rewrite(file1);
WRITELN('R,G');         {R=RADIUS OF SPHERICAL PART,  G=DISTANCE FROM THE PLANE)
READLN(R,G);
WRITELN(file1,'Radius of spherical part =',R:8:4,'  distance from plate =',G:8:4);
WRITELN(file1,'==============================');
WRITELN('L,A1');         {L=LENGTH OF FIRST LINE CHARGE, A1=MULTIPLYING FACTOR FOR LENGTH)
```

```
READLN(L,A1);
WRITELN(file1,'Length of first line charge =',L:8:4,' multyplying factor =',A1:8:4);
WRITELN(file1,'==============================');
ZN[1]:=R+G;
WRITELN(file1,ZN[1]:8:4);
ZN[2]:=R+G+L;
WRITELN(file1,ZN[2]:8:4);
FOR I:=3 TO N DO
BEGIN
J:=I-1;
K:=I-2;
ZN[I]:=A1*(ZN[J]-ZN[K])+ZN[J];
WRITELN(file1,ZN[I]:8:4)
END;
WRITELN(file1,'================================');
WRITELN(file1);
FOR B1:=1 TO 6 DO
BEGIN
THETA:=(B1-1)*15*3.1419/180;
PQ[B1,1]:=R*SIN(THETA);
PQ[B1,2]:=G+R*(1-COS(THETA));
WRITE(file1,PQ[B1,1]:8:4,PQ[B1,2]:8:4);
WRITELN(file1)
END;
FOR C:=7 TO (N+6) DO
BEGIN
PQ[C,1]:=R;
PQ[C,2]:=((ZN[C-6]+R+G)/2);
WRITE(file1,PQ[C,1]:8:4,PQ[C,2]:8:4);
WRITELN(file1)
END;
FOR D:=(N+7) TO M DO
BEGIN
THETA:=(3.1419/2)*((D-N-7)/(M-N-6));
writeln(file1,'theta=',theta:8:4);
PQ[D,1]:=R*SIN(THETA);
PQ[D,2]:=G+R*(1-COS(THETA));
WRITE(file1,PQ[D,1]:8:4,PQ[D,2]:8:4);
WRITELN(file1)
END;
WRITELN(file1,'======================');
FOR U:=1 TO M DO
BEGIN
S:=U;
M1:=(1/SQRT(SQR(PQ[S,1])+SQR(PQ[S,2]-ZN[1])));
M2:=(1/SQRT(SQR(PQ[S,1])+SQR(PQ[S,2]+ZN[1])));
MAT[U,1]:=(M1-M2);
FOR V:=2 TO N DO
BEGIN
D1:=1/(ZN[V]-ZN[V-1]);
if pq[s,1]=0.0 then
begin
d11:=(zn[v]-pq[s,2]);
d12:=(zn[v-1]-pq[s,2]);
d21:=(zn[v-1]+pq[s,2]);
d22:=(zn[v]+pq[s,2]);
mat[u,v]:=d1*ln((d11/d12)*(d21/d22));
end
else
begin
d11:=(ZN[V]-PQ[S,2]+SQRT(SQR(ZN[V]-PQ[S,2])+SQR(PQ[S,1])));
d12:=(ZN[V-1]-PQ[S,2]+SQRT(SQR(ZN[V-1]-PQ[S,2])+SQR(PQ[S,1])));
d21:=(ZN[V-1]+PQ[S,2]+SQRT(SQR(ZN[V-1]+PQ[S,2])+SQR(PQ[S,1])));
d22:=(ZN[V]+PQ[S,2]+SQRT(SQR(ZN[V]+PQ[S,2])+SQR(PQ[S,1])));
MAT[U,V]:=d1*ln((d11/d12)*(d21/d22));
END ;
```

```
write(file1,mat[u,v]:8:4)
end;
writeln(file1)
end;
FOR U:=1 TO N DO
BEGIN
FOR V:=1 TO N DO
BEGIN
CAT[U,V]:=MAT[U,V]
END;
END;
INVERSE(CAT,CHARGE);
writeln(file1,'=================================================================');
writeln(file1,'charge vector is');
writeln(file1,'==================');
writeln(file1);
For u:=1 to n do
begin
writeln(file1,CHARGE[U,1]:8:8);
end;
writeln(file1,'=================================================');
{ERROR CALCULATION
====================}
writeln(file1,'ERROR CALCULATION');
ERROR:=0.0;
FOR I:=(N+1) TO M DO
BEGIN
I1:=I-N;
VOL[I1]:=0.0;
FOR J:=1 TO N DO
BEGIN
VOL[I1]:=VOL[I1]+MAT[I,J]*CHARGE[J,1]
END;
WRITELN(file1,'voltage=',VOL[I1]:8:8);
ERROR:=ERROR+SQR(1-VOL[I1]);
eror:=1-vol[i1];
writeln(file1,'error=',eror:8:8)
END;
writeln(file1,'cummulative square error=',error:8:8);
{CALCULATION OF EQUIPOTENTIAL SURFACES}
writeln(file1,'CALCULATION OF EQUIPOTENTIAL SURFACES');
DH:=G/5;
DRI:=R/5;
FOR O:=1 TO 5 DO
BEGIN
RI:=0.0;
ZI:=O*DH;
WRITELN(file1,'RI=',RI,'  ZI=',ZI);
WRITELN('RI=',RI,'  ZI=',ZI);
WHILE ZI<(G+R) DO
BEGIN
E1:=EXP(1.5*LN(SQR(RI)+SQR(ZI-ZN[1])));
E2:=EXP(1.5*LN(SQR(RI)+SQR(ZI+ZN[1])));
ER:=CHARGE[1,1]*RI*((1.0/E1)-(1.0/E2));
EZ:=CHARGE[1,1]*(ZI-ZN[1])*((1.0/E1)-(1.0/E2));
FOR P:= 2 TO N DO
BEGIN
G1:=SQRT(SQR(RI)+SQR(ZN[P]-ZI));
G2:=SQRT(SQR(RI)+SQR(ZN[P-1]+ZI));
DL1:=SQRT(SQR(RI)+SQR(ZN[P-1]-ZI));
DL2:=SQRT(SQR(RI)+SQR(ZN[P]+ZI));
IF RI=0.0 THEN
BEGIN
ER:=0.0
END
ELSE
```

```
BEGIN
F1:=(ZN[P]-ZI)/(RI*G1);
F2:=(ZN[P-1]-ZI)/(RI*DL1);
F3:=(ZN[P-1]+ZI)/(RI*G2);
F4:=(ZN[P]+ZI)/ (RI*DL2);
ER:=ER-((CHARGE[P,1])/(ZN[P]-ZN[P-1]))*(F1-F2+F3-F4)
END;
EZ:=EZ-((CHARGE[P,1])/(ZN[P]-ZN[P-1]))*((1/G1)-(1/DL1)-(1/G2)+(1/DL2))
END;{OF ER & EZ CALCULATION}
WRITELN('ER=',ER:8:4,'  EZ=',EZ:8:4);
WRITELN('ER=',ER:8:4,'  EZ=',EZ:8:4);
WRITELN;
{IF ER=0.0 THEN
BEGIN
DZ:=0.0;
DR:=DRI
END
ELSE
BEGIN}
DZ:=-(ER/EZ)*DRI;
{END;}
ZI:=ZI+DZ;
RI:=RI+DRI;
WRITELN(file1,'RI=',RI,'  ZI=',ZI);
WRITELN('RI=',RI,'  ZI=',ZI);
writeln('-------------------------------------------------------');
writeln('-------------------------------------------------------')
END;{OF WHILE LOOP}
WRITELN('=======================================================');
WRITELN(file1)
END;{OF O LOOP}
writeln('=======================================================');
{END OF EQUIPOTENTIAL SURFACE CALCULAATION
=========================================}
writeln('end of execution');
close(file1)
END.
```

```
program rogo;
USES CRT;
CONST N=7;  M=1;
TYPE
MATRIX1=ARRAY [1..N,1..N] OF REAL;
MATRIX2=ARRAY [1..N,1..M] OF REAL;
MATRIX3=ARRAY [1..N,1..2] OF REAL;
VAR XY:ARRAY[1..7,1..7] OF REAL;
PQ:ARRAY[1..8,1..2] OF REAL;
MAT:MATRIX1;
CHARGE:MATRIX2;
B:MATRIX2;
RS:MATRIX3;
RAT:MATRIX1;
VOL:MATRIX2;
ELEC,e221,e222,EROOR,EROR,X,DRI,DX,P,Q,Y, A1,A2,A11,A12,K11,K12,E11,E12,RI,ZI,ER,EZ,AA1,AA2,
a111,a112,E21,E22,k111,k112,e111,e112,e1o,e2o,KK1,KK2,EE1,EE2,K1K,K2K,WR1,WR2,WZ1,WZ2,DZ,E1,
f,I,ii,s1,t1,J,S,G,H,T,p1,q1,o,RU,u,v,mm:INTEGER;
F1,F2:TEXT;
PROCEDURE INVERSE(A:MATRIX1; VAR B:MATRIX2);
CONST NM=50;
      N=7; M=1;
VAR  IPIV:ARRAY[1..NM] OF INTEGER;
    INDXR:ARRAY[1..NM] OF INTEGER;
    INDXC:ARRAY[1..NM] OF INTEGER;
    BIG,DUM,PIVINV:REAL;
    I,J,V,U,LL,K,L,P,Q,ICOL,IROW:INTEGER;
    BEGIN

{ FOR P:=1 TO N DO
  BEGIN
   FOR Q:=1 TO N DO
    BEGIN
     READ(file1,A[P,Q]);
    END;
    READLN(file1)
    END;  }
  FOR P:=1 TO N DO
   BEGIN
    FOR Q:=1 TO M DO
     BEGIN
```

```
    B[P,Q]:=1.0;
    END;
     END;
FOR J:=1 TO N DO
  BEGIN
   IPIV[J]:=0;
  END;
 FOR I:=1 TO N DO
  BEGIN
   BIG:=0.0;
   FOR J:=1 TO N DO
    BEGIN
     IF (IPIV[J]<>1) THEN
      BEGIN
       FOR K:=1 TO N DO
       BEGIN
        IF (IPIV[K]=0) THEN
         BEGIN
          IF (ABS(A[J,K]))=BIG) THEN
           BEGIN
            BIG:=ABS(A[J,K]);
            IROW:=J;
            ICOL:=K
           END; END
           ELSE
           IF (IPIV[K]>1 ) THEN
            BEGIN
             WRITELN('********** SINGULAR POINT ************');
             writeln;
             READLN
           END;
         END
      END
      END;
      IPIV[ICOL]:=IPIV[ICOL]+1;
      IF (IROW <> ICOL) THEN
       BEGIN
        FOR L:=1 TO N DO
        BEGIN
         DUM:=A[IROW,L];
         A[IROW,L]:=A[ICOL,L];
         A[ICOL,L]:=DUM
        END;
        FOR L:=1 TO M DO
         BEGIN
          DUM:=B[IROW,L];
          B[IROW,L]:=B[ICOL,L];
          B[ICOL,L]:=DUM
         END;
       END;
       INDXR[I]:=IROW;
       INDXR[I]:=ICOL;
       IF (A[ICOL,ICOL]=0.0) THEN
        BEGIN
         WRITELN('********* IT IS A SINGULAR  MATRIX ********') ;
         READLN
        END;
       PIVINV:=(1.0/A[ICOL,ICOL]);
       A[ICOL,ICOL]:=1.0;
       FOR L:=1 TO N DO
        BEGIN
         A[ICOL,L]:=A[ICOL,L]*PIVINV
        END;
      FOR L:=1 TO M DO
      BEGIN
       B[ICOL,L]:=B[ICOL,L]*PIVINV
```

```
        END;
        FOR LL:=1 TO N  DO
          BEGIN
           IF (LL<>ICOL) THEN
           BEGIN
            DUM:=A[LL,ICOL];
            A[LL,ICOL]:=0.0;
            FOR L:=1 TO N DO
             BEGIN
              A[LL,L]:=A[LL,L]-A[ICOL,L]*DUM;
             END;
             FOR L:=1 TO M DO
             BEGIN
              B[LL,L]:=B[LL,L]-B[ICOL,L]*DUM
             END;
           END;
          END;
         END;
         FOR L:=N DOWNTO  1  DO
          BEGIN
            IF (INDXR[L]<>INDXC[L]) THEN
             BEGIN
             FOR K:=1 TO N DO
             BEGIN
              DUM:=A[K ,INDXR[L]];
              A[K,INDXR[L]]:=A[K,INDXC[L]];
              A[K,INDXC[L]]:=DUM
             END;
           END;
          END;
        END;


{END OF PROCEDURE INVERSE }
{=============================}

BEGIN  { main }
ASSIGN(F1,'RAJ.PRN');
REWRITE(F1);
CLRSCR;
{================================================}
WRITELN(F1,'CONTOUR POINTS,RING RADII & RING LOCATIONS ARE');
{=====================================================}
X:=0.5 ;
DX:=0.50;
PQ[1,1]:=0.0;
PQ[1,2]:=0.5;
WRITE(F1,PQ[1,1]:8:4);
WRITE(F1,PQ[1,2]:8:4);
WRITE(F1,'      ');
XY[1,1]:=0.5;
XY[1,2]:=1.250;
WRITE(F1,XY[1,1]:8:4);
WRITE(F1,'  ');
WRITE(F1,XY[1,2]:8:4);
WRITELN(F1);
PQ[2,1]:=0.5;
PQ[2,2]:=0.52;
WRITE(F1,PQ[2,1]:8:4);
WRITE(F1,'  ');
WRITE(F1,PQ[2,2]:8:4);
WRITE(F1,'  ');
WRITE(F1,'      ');
P:=0.5;
FOR I:=2 TO 7 DO
BEGIN
```

```
J:=I+1;
X:=X+(1.5*DX/i);
P:=P+DX;
Y:=1.487+0.00266*EXP(3.23*(X));
Q:=Y-1.0;
XY[I,1]:=X;
XY[I,2]:=Y;
PQ[J,1]:=P;
PQ[J,2]:=Q;
WRITE(F1,XY[I,1]:8:4);
WRITE(F1,'  ');
WRITE(F1,XY[I,2]:8:4);
WRITELN(F1);
WRITE(F1,PQ[J,1]:8:4);
WRITE(F1,'  ');
WRITE(F1,PQ[J,2]:8:4);
WRITE(F1,'     ');
END;
WRITELN(F1);
WRITELN(F1,'================================');
WRITELN(F1,'POTENTIAL COFFECIENTS ');
WRITELN(F1,'================================');
FOR S:=1 TO 7 DO
BEGIN
FOR T:=1 TO 7 DO
BEGIN
A1:=SQRT(SQR(PQ[S,1]+XY[T,1])+SQR(PQ[S,2]-XY[T,2]));
A2:=SQRT(SQR(PQ[S,1]+XY[T,1])+SQR(PQ[S,2]+XY[T,2]));
K1:=2*SQRT(PQ[S,1]*XY[T,1])/A1;
K2:=2*SQRT(PQ[S,1]*XY[T,1])/A2;
IF K1=0.0 THEN
begin
E1:=3.142/2
end
ELSE
BEGIN
E11:=1+0.25*SQR(K1)+(9/64)*EXP(4*LN(K1));
E12:=(25/256)*EXP(6*LN(K1))+(1225/16384)*EXP(8*LN(K1));
E1:=(3.142/2)*(E11+ E12);
END;
IF K2=0.0 THEN
BEGIN
E2:=3.142/2
END
ELSE
BEGIN
E21:=1+0.25*SQR(K2)+(9/64)*EXP(4*LN(K2))+(25/256)*EXP(6*LN(K2));
E22:=(1225/16384)*EXP(8*LN(K2));
E2:=(3.142/2)*(E21+E22);
END;
MAT[S,T]:=(2/3.142)*((E1/A1)-(E2/A2));
WRITE(F1,MAT[S,T]:8:4);
WRITE(F1,' ');
END;
WRITELN(F1);
END;
WRITELN(F1,'================================');
{CALLING THE PROCEDURE INVERSE
 ****************************** }
INVERSE(MAT, CHARGE );
WRITELN(F1,'CHARGE VECTOR IS');
FOR I:=1 TO N DO
BEGIN
WRITELN(F1,CHARGE[I,1]:8:4)
END;
WRITELN(F1);
```

```
  DRI:=0.1;
 MM:=1;

{=============================================================================
=============================================================================}
CLRSCR;
WRITELN('ERROR CALCULATION');
WRITELN('++++++++++++++++++++++++++');
rs[1,1]:=0.25;  rs[2,1]:=0.6 ; rs[3,1]:=0.7;    rs[4,1]:=0.8;
rs[1,2]:=0.5 ;
rs[5,1]:=0.9 ;  rs[6,1]:=1.01;  rs[7,1]:=1.1;
for ii:=2 to 7 do
begin
rs[ii,2]:=0.487+0.00266*exp(3.23*rs[ii,1]) .
end;
WRITELN(F1,'TEST POINTS ARE');
FOR I:=1 TO N DO
BEGIN
FOR J:=1 TO 2 DO
BEGIN
WRITE(F1,RS[I,J]:8:4);
WRITE(F1,'    ')
END;
WRITELN(F1)
END;
WRITELN(F1,'-------------------------------------------------');
WRITELN(F1,'POTENTIAL COFFICIENTS FOF TEST POINTS ARE');
for S1:=1 to 7 do
begin
for T1:=1 to 7 do
begin
A111:=SQRT(SQR(RS[S1,1]+XY[T1,1])+SQR(RS[S1,2]-XY[T1,2]));
A112:=SQRT(SQR(RS[S1,1]+XY[T1,1])+SQR(RS[S1,2]+XY[T1,2]));
K111:=2*SQRT(RS[S1,1]*XY[T1,1])/A111;
K112:=2*SQRT(RS[S1,1]*XY[T1,1])/A112;
IF K111=0.0 THEN
BEGIN
 E1o:=3.142/2
END
ELSE
BEGIN
E111:=1+0.25*SQR(K111)+(9/64)*EXP(4*LN(K111));
E112:=(25/256)*EXP(6*LN(K111))+(1225/16384)*EXP(8*LN(K111));
E1o:=(3.142/2)*(E111+ E112);
END;
IF K112=0.0 THEN
BEGIN
E2o:=3.142/2
END
ELSE
BEGIN
E221:=1+0.25*SQR(K112)+(9/64)*EXP(4*LN(K112))+(25/256)*EXP(6*LN(K112));
E222:=(1225/16384)*EXP(8*LN(K112));
E2o:=(3.142/2)*(E221+E222);
END;
RAT[S1,T1]:=(2/3.142)*((E1o/A111)-(E2o/A112));
WRITE(F1,RAT[S1,T1]:8:4);
END;
WRITELN(F1);
END;
WRITELN(F1) ;
CLRSCR;
{MULTIPLICATION OF RAT WITH CHARGE AND ERROR CALCULATION
=========================================================}
EROOR:=0.0;
FOR P1:=1 TO 7 DO
```

```
  ]:=0.0;
  : 1 TO 7 DO

 ]:=VOL[P1,1]+MAT[P1,Q1]*CHARGE[Q1,1]

  (F1,'VOLTAGE AT THE TEST POINT=',VOL[P1,1]:4:12);
 1-VOL[P1,1]) ;
 EROOR+SQR(1-VOL[P1,1]);
 (F1,'ERROR AT TH TEST POINT=',EROR:4:12);
 (F1,'----------------------------------------')

 (F1);
 (F1,'CUMMULATIVE SQUARE ERROR =',EROOR:4:8);
 (F1,'equipotential surface calculation');
 (F1,'==================================');
 =1 TO 5 DO

 0;
 0.1;
 N('RI=',RI:8:3,'  ZI=',ZI:8:3);
 N(F1,'RI=',RI:8:3,'  ZI=',ZI:8:3);
 (ZI(0.96) DO

 .0;
 .0;
 :=1 TO 7 DO

  AA1:=SQRT(SQR(RI+XY[H,1])+SQR(ZI-XY[H,2]));
  AA2:=SQRT(SQR(RI+XY[H,1])+SQR(ZI+XY[H,2]));
  B1:=SQRT(SQR(RI-XY[H,1])+SQR(ZI-XY[H,2]));
  B2:=SQRT(SQR(RI-XY[H,1])+SQR(ZI+XY[H,2]));
  KK1:=2*SQRT(RI*XY[H,1])/AA1;
  KK2:=2*SQRT(RI*XY[H,1])/AA2;
  IF KK1=0.0  THEN
   BEGIN
   EE1:=3.142/2
   END
   ELSE
```

```
(3.142/2)*(1+(1/4)*SQR(KK1)+(9/64)*EXP(4*LN(KK1))+(25/256)*EXP(6*LN(KK1))+(1225/16384)*EXP(8*LN(KK1)))

K2=0.0 THEN

3.142/2



(3.142/2)*(1+(1/4)*SQR(KK2)+(9/64)*EXP(4*LN(KK2))+(25/256)*EXP(6 *LN(KK2))+(1225/16384)*EXP(8*LN(KK2)

1=0.0 THEN

=(3.142/2)



(3.142/2)*(1-(1/4)*SQR(KK1)-(3/64)*EXP(4*LN(KK1))-(5/256)*EXP(6*LN(KK1))-(175/16384)*EXP(8*LN(KK1)));

2=0.0 THEN

=(3.142/2)



=(3.142/2)*(1-(1/4)*SQR(KK2)-(3/64)*EXP(4*LN(KK2))-(5/256)*EXP(6*LN(KK2))-(175/16384)*EXP(8*LN(KK2)))
```

```
*(SQR(XY[H,1])-SQR(RI)+SQR(ZI -XY[H,2]))*K1K;
*(SQR(XY[H,1])-SQR(RI)+SQR(ZI +XY[H,2]))*K2K;

=0.0 THEN

.0


N
ER-(CHARGE[H,1]/(3.142*RI))*(((WR1-SQR(B1)*EE1)/(AA1*SQR(B1)))-((WR2-SQR(B2)*EE2)/(AA2*SQR(B2))));

=((ZI-XY[H,2])*K1K)/(AA1*SQR(B1));
=((ZI+XY[H,2])*K2K)/((AA2*SQR(B2)));
EZ+(CHARGE[H,1]*(2/3.142)*(WZ1+WZ2))

ELN(' ER=  ',ER:8:3,'  EZ=  ',EZ:8:3);
ELN(' ER=  ',ER:8:3,'  EZ=  ',EZ:8:3);
:=SQRT(SQR(ER)+SQR(EZ));
ELN('ELECTRIC FIELD =',ELEC:8:4);
ELN('ELECTRIC FIELD =',ELEC:8:4);
=-(ER/EZ)*DRI;
*ZI+DZ;
*RI+DRI;
ELN('-------------------------------------------------------');
ELN(' RI=  ',RI:8:3,'  ZI=  ',ZI:8:3);
ELN;
ELN('-------------------------------------------------------');
ELN(F1,' RI=  ',RI:8:3,'  ZI=  ',ZI:8:3);
ELN;
;(OF WHILE LOOP)
ELN ('=======================================================');
ELN (F1,'=======================================================');
; (OF G LOOP)
SE(F1);
ELN('END OF EXECUTION')
).
```

```
CONTOUR POINTS,RING RADII & RING LOCATIONS ARE
  0.0000   0.5000        0.5000     1.2500
  0.5000     0.5200          0.8750     1.5319
  1.0000     0.5319        1.1250     1.5877
 `1.5000     0.5877        1.3125     1.6715
  2.0000     0.6715        1.4625     1.7865
  2.5000     0.7865        1.5875     1.9355
  3.0000     0.9355        1.6946     2.1210
  3.5000     1.1210
================================
POTENTIAL COFFECIENTS
================================
  0.5600    0.2871    0.2174    0.1743    0.1450    0.1233    0.1060
  0.4941    0.2817    0.2195    0.1784    0.1494    0.1274    0.1097
  0.3089    0.2221    0.1853    0.1577    0.1364    0.1192    0.1046
  0.1897    0.1648    0.1469    0.1317    0.1190    0.1080    0.0979
  0.1227    0.1209    0.1134    0.1063    0.1000    0.0941    0.0884
  0.0855    0.0913    0.0888    0.0861    0.0836    0.0813    0.0787
  0.0637    0.0715    0.0713    0.0709    0.0706    0.0704    0.0700
================================
CHARGE VECTOR IS
-94.3635
-1298.1773
19857.6269
-67115.9749
95338.7670
-61866.7254
15211.9073

TEST POINTS ARE
  0.2500      0.5000
  0.6000      0.5055
  0.7000      0.5125
  0.8000      0.5222
  0.9000      0.5357
  1.0100      0.5565
  1.1000      0.5799
------------------------------------------------------
POTENTIAL COFFICIENTS FOF TEST POINTS ARE
  0.5397  0.2841  0.2167  0.1743  0.1450  0.1233  0.1060
  0.4420  0.2639  0.2083  0.1707  0.1436  0.1228  0.1059
  0.4095  0.2561  0.2048  0.1692  0.1431  0.1229  0.1063
  0.3776  0.2476  0.2007  0.1674  0.1426  0.1230  0.1068
  0.3480  0.2392  0.1966  0.1656  0.1421  0.1234  0.1076
  0.3192  0.2307  0.1926  0.1641  0.1421  0.1243  0.1091
  0.2991  0.2250  0.1902  0.1636  0.1428  0.1258  0.1110

VOLTAGE AT THE TEST POINT=0.99999997951
ERROR AT TH TEST POINT=0.00000002049
----------------------------------------
VOLTAGE AT THE TEST POINT=1.00000000370
ERROR AT TH TEST POINT=-0.00000000373
----------------------------------------
VOLTAGE AT THE TEST POINT=0.99999997765
ERROR AT TH TEST POINT=0.00000002235
----------------------------------------
VOLTAGE AT THE TEST POINT=0.99999999255
ERROR AT TH TEST POINT=0.00000000745
----------------------------------------
VOLTAGE AT THE TEST POINT=1.00000001120
ERROR AT TH TEST POINT=-0.00000001118
----------------------------------------
VOLTAGE AT THE TEST POINT=1.00000000000
ERROR AT TH TEST POINT=0.00000000000
----------------------------------------
VOLTAGE AT THE TEST POINT=0.99999999814
```

ERROR AT TH TEST POINT=0.00000000186

CUMMULATIVE SQUARE ERROR =0.00000000
equipotential surface calculation

RI=	0.000	ZI=	0.100
RI=	0.100	ZI=	0.100
RI=	0.200	ZI=	0.115
RI=	0.300	ZI=	0.147
RI=	0.400	ZI=	0.201
RI=	0.500	ZI=	0.285
RI=	0.600	ZI=	0.407
RI=	0.700	ZI=	0.561
RI=	0.800	ZI=	0.716
RI=	0.900	ZI=	0.860
RI=	1.000	ZI=	1.017
RI=	0.000	ZI=	0.200
RI=	0.100	ZI=	0.200
RI=	0.200	ZI=	0.214
RI=	0.300	ZI=	0.244
RI=	0.400	ZI=	0.293
RI=	0.500	ZI=	0.367
RI=	0.600	ZI=	0.470
RI=	0.700	ZI=	0.595
RI=	0.800	ZI=	0.728
RI=	0.900	ZI=	0.862
RI=	1.000	ZI=	1.017
RI=	0.000	ZI=	0.300
RI=	0.100	ZI=	0.300
RI=	0.200	ZI=	0.312
RI=	0.300	ZI=	0.338
RI=	0.400	ZI=	0.381
RI=	0.500	ZI=	0.444
RI=	0.600	ZI=	0.527
RI=	0.700	ZI=	0.629
RI=	0.800	ZI=	0.742
RI=	0.900	ZI=	0.867
RI=	1.000	ZI=	1.018
RI=	0.000	ZI=	0.400
RI=	0.100	ZI=	0.400
RI=	0.200	ZI=	0.410
RI=	0.300	ZI=	0.431
RI=	0.400	ZI=	0.465
RI=	0.500	ZI=	0.515
RI=	0.600	ZI=	0.581
RI=	0.700	ZI=	0.662
RI=	0.800	ZI=	0.758
RI=	0.900	ZI=	0.872
RI=	1.000	ZI=	1.019
RI=	0.000	ZI=	0.500
RI=	0.100	ZI=	0.500
RI=	0.200	ZI=	0.507
RI=	0.300	ZI=	0.521
RI=	0.400	ZI=	0.545
RI=	0.500	ZI=	0.581
RI=	0.600	ZI=	0.630
RI=	0.700	ZI=	0.693
RI=	0.800	ZI=	0.774
RI=	0.900	ZI=	0.879
RI=	1.000	ZI=	1.020

```
program general;
label 200,500,300,400,600;
CONST CO=9.0e09;
      NE=3;
      NB=7;
      EB=10;
      EBB=17;
      N=17;
TYPE MAT1=ARRAY[1..EBB,1..2] OF REAL;
     MAT2=ARRAY[1..EB,1..2] OF REAL;
     MAT3=ARRAY[1..EBB,1..EBB] OF REAL;
     MAT4=ARRAY[1..NB,1..EBB] OF REAL;
     MAT5=ARRAY[1..NB] OF REAL;
     MAT6=ARRAY[1..EBB,1..1] OF REAL;
     MAT7=ARRAY[1..EBB,1..3] OF REAL;
VAR
     C1,NOM,ANS1,G,U,E1,E2,D11,D12,D21,D22,ED1,ED2,M11,M12,M21,M22,I1,I2,P1,P2,P3,Q1,Q2:INTEGER;
     GI,MM,FO,ANS3,LO,H11,OO,H12,HS1,H22,ANSO,G1,G2,H1,H2,ANS,X1,Y1,K1,L1,M1,N1,O1,R1,I,J,K:INTEG
     RZ:MAT1;
     PQ:MAT2;
     MAT:MAT3;
     TH1:MAT5;
     TH2:MAT4;
     THETA:MAT4;
     CHARGE:MAT6;
     SC:MAT2;
     CS:MAT2;
     HH:MAT7;
     TAN:ARRAY[1..EBB] OF REAL;
     ERR:MAT1;
     EROR:ARRAY[1..EBB] OF REAL;
     VOL:ARRAY[1..EBB] OF REAL;
     CUM,TANG1,RIS,ZIS,ZI,AO,BO,RIE,ZIE,CO,A2,B2,CR,ER,EZ,DR,DZ,DL,EP,RI,EP2:REAL;
     D1,D2,RI1,RI2,ZI1,ZI2,RIA,ZIA:REAL;
FI,FJ:TEXT;
FUNCTION F(RZ:MAT1;PQ:MAT2;F1,F2:INTEGER):REAL;
  BEGIN
    F:=(1/SQRT(SQR(RZ[F1,1]-PQ[F2,1])+SQR(RZ[F1,2]-PQ[F2,2])));
  END;
FUNCTION FER(RZ:MAT1;CHARGE:MAT6;RI,ZI:REAL;V:INTEGER):real;
          VAR A,B,C:REAL;
          BEGIN
          A:=RI-RZ[V,1];
          B:=ZI-RZ[V,2];
          C:=EXP(1.5*LN(SQR(A)+SQR(B)));
          FER:=CHARGE[V,1]*(A/C);
          END;
FUNCTION FEZ(RZ:MAT1;CHARGE:MAT6;RI,ZI:REAL;W:INTEGER):real;
          VAR A,B,C:REAL;
          BEGIN
          A:=RI-RZ[W,1];
          B:=ZI-RZ[W,2];
          C:=EXP(1.5*LN(SQR(A)+SQR(B)));
          FEZ:=CHARGE[W,1]*(B/C)
          END;
FUNCTION FV(RZ:MAT1;ERR:MAT1;CHARGE:MAT6;G2,G1:INTEGER):REAL;
          BEGIN
          FV:=CHARGE[G2,1]*(1/SQRT(SQR(RZ[G2,1]-ERR[G1,1])+SQR(RZ[G2,2]-ERR[G1,2])))
          END;
FUNCTION FS(RZ:MAT1;PQ:MAT2;SC:MAT2;U,V,W:INTEGER):REAL;
          VAR L:REAL;
          BEGIN
```

```
        L:=EXP(1.5*LN(SQR(RZCU,1]-PQCV,1])+SQR(RZCU,2]-PQCV,2])));
        FS:=((RZCU,1]-PQCV,1])*SCCW,2]+(RZCU,2]-PQCV,2])*SCCW,1])/L
        END;
FUNCTION FH(RZ:MAT1;HH:MAT7;CS:MAT2;PO,LO:INTEGER):REAL;
        VAR LI:REAL;
        BEGIN
        LI:=EXP(1.5*LN(SQR(RZCPO,1]-HHCLO,1])+SQR(RZCPO,2]-HHCLO,2])));
        FH:=((RZCPO,1]-HHCLO,1])*CSCLO,1]+(RZCPO,2]-HHCLO,2])*CSCLO,2])/LI
        END;
PROCEDURE   INVERSE(A:MAT3; VAR B:MAT6);
CONST NM=50;
N=17;
M=1;
NE=3;
NB=7;
EB=10;
VAR INDXR:ARRAYC1..NM] OF INTEGER;
    INDXC:ARRAYC1..NM] OF INTEGER;
    IPIV:ARRAYC1..NM] OF INTEGER;
    BIG,PIVINV,DUM:REAL;
    I,J,U,V,LL,L,K,P,Q,ICOL,IROW:INTEGER;
    BEGIN(OF PROCEDURE)
    FOR P:=1 TO NE DO
    BEGIN
    FOR Q:=1 TO M DO
    BEGIN
    BCP,Q]:=1.0;
    END;
    END;
    FOR P:=(NE+1) TO N DO
    BEGIN
    FOR Q:=1 TO M DO
    BEGIN
    BCP,Q]:=0.0;
    END;
    END;
    FOR J:=1 TO N DO
    BEGIN
    IPIVCJ]:=0;
    END;
    FOR I:=1 TO N DO
    BEGIN
    BIG:=0.0;
    FOR J:=1 TO N DO
    BEGIN
    IF (IPIVCJ]<>1) THEN
    BEGIN
    FOR K:=1 TO N DO
    BEGIN
    IF (IPIVCK]=0) THEN
    BEGIN
    IF (ABS(ACJ,K])>=BIG) THEN
    BEGIN
    BIG:=ABS(ACJ,K]);
    IROW:=J;
    ICOL:=K
    END;
    END
    ELSE
    IF (IPIVCK]>1) THEN
    BEGIN
    WRITELN('SINGULAR POINT');
```

```
READLN
END;
END
END
END;
IPIV[ICOL]:=IPIV[ICOL]+1;
IF (IROW<>ICOL) THEN
BEGIN
FOR L:=1 TO N DO
BEGIN
DUM:=A[IROW,L];
A[IROW,L]:=A[ICOL,L];
A[ICOL,L]:=DUM;
END;
FOR L:=1 TO M DO
BEGIN
DUM:=B[IROW,L];
B[IROW,L] :=B[ICOL,L];
B[ICOL,L]:=DUM
END;
END;
INDXR[I]:=IROW;
INDXR[I]:=ICOL;
IF (A[ICOL,ICOL]=0.0) THEN
BEGIN
WRITELN('SINGULAR MATRIX');
READLN
END;
PIVINV:=(1.0/A[ICOL,ICOL]);
A[ICOL,ICOL]:=1.0;
FOR L:=1 TO N DO
BEGIN
A[ICOL,L]:=A[ICOL,L]*PIVINV
END;
FOR L:=1 TO M DO
BEGIN
B[ICOL,L]:=B[ICOL,L]*PIVINV
END;
FOR LL:=1 TO N DO
BEGIN
IF (LL<>ICOL) THEN
BEGIN
DUM:=A[LL,ICOL];
A[LL,ICOL]:=0.0;
FOR L:=1 TO N DO
BEGIN
A[LL,L]:=A[LL,L]-A[ICOL,L]*DUM;
END;
FOR L:=1 TO M DO
BEGIN
B[LL,L]:=B[LL,L]-B[ICOL,L]*DUM
END;
END;
END;
END;
FOR  L:=N DOWNTO 1 DO
BEGIN
IF (INDXR[L]<>INDXC[L]) THEN
BEGIN
FOR K:=1 TO N DO
BEGIN
DUM:=A[K,INDXR[L]];
```

```
    ACK,INDXR[L]]:=ACK,INDXC[L]];
    ACK,INDXC[L]]:=DUM
    END;END;
    END;
    WRITELN('================================');
    END;{OF PROCEDURE}
BEGIN{OF MAIN PROGRAMME}
  ASSIGN(FI,'MAT.DAT ');
  REWRITE(FI);
  ASSIGN(FJ,'DAT.PRN');
  RESET(FJ);
  WRITELN(FI,'GIVE THE LOCATION OF SIMULATION CHARGES INSIDE THE ELECTRODE');
  WRITELN('GIVE THE LOCATION OF SIMULATION CHARGES INSIDE THE ELECTRODE');
  FOR E1:=1 TO NE DO
  BEGIN
  FOR E2:=1 TO 2 DO
  BEGIN
  READ(FJ,RZ[E1,E2]);
  WRITE(FI,RZ[E1,E2]:8:4,' ');
  END;
  READLN(FJ);
  WRITELN(FI);
  END;
  WRITELN(FI,'GIVE THE LOCATION OF SIMULATION CHARGES INSIDE THE AIR');
  WRITELN('GIVE THE LOCATION OF SIMULATION CHARGES INSIDE THE AIR');
  FOR D11:=1 TO NB DO
  BEGIN
  FOR D12:=1 TO 2 DO
  BEGIN
  READ(FJ,RZ[(D11+NE),D12]);
  WRITE(FI,RZ[(D11+NE),D12]:8:4,' ' );
  END;
  WRITELN(FI);
  READLN(FJ);
  END;
  WRITELN(FI,'GIVE THE LOCATION OF SIMULATION CHARGES INSIDE THE DIELECTRIC');
  WRITELN('GIVE THE LOCATION OF SIMULATION CHARGES INSIDE THE DIELECTRIC ');
  FOR D21:=1 TO NB DO
  BEGIN
  FOR D22:=1 TO 2 DO
  BEGIN
  READ(FJ,RZ[(D21+EB),D22]);
  WRITE(FI,RZ[(D21+EB),D22]:8:4,' ');
  END;
  READLN(FJ);
  WRITELN(FI);
  END;
  WRITELN(FI);
  WRITELN(FI,'GIVE THE NUMBER OF CONTOUR POINTS ON  THE AIR-E INTERFACE');
  WRITELN('GIVE THE NUMBER OF CONTOUR POINTS ON  THE AIR-E INTERFACE');
  READLN(FJ,ED1);
  WRITELN(FI,ED1);
  ED2:=NE-ED1;
  IF (ED1>0.0) THEN
  BEGIN
  WRITELN(FI,'GIVE THE LOCATION OF ABOVE CONTOUR POINTS');
  WRITELN('GIVE THE LOCATION OF ABOVE CONTOUR POINTS');
  FOR M11:=1 TO ED1 DO
  BEGIN
  FOR M12:=1 TO 2 DO
  BEGIN
  READ(FJ,PG[M11,M12]);
```

```
  WRITE(FI,PQE[M11,M12]:8:4,' ');
  END;
  READLN(FJ);
  WRITELN(FI);
  END;
  END;
  IF (ED2>0.0) THEN
  BEGIN
  WRITELN(FI,'GIVE THE LOCATION OF CONTOUR POINTS ON THE THE D-E INTERFACE');
  WRITELN('GIVE THE LOCATION OF CONTOUR POINTS ON THE THE D-E INTERFACE');
  FOR M21:=1 TO ED2 DO
  BEGIN
  FOR M22:=1 TO 2 DO
  BEGIN
  READ(PQE(M21+ED1),M22]);
  WRITE(FI,PQE(M21+ED1),M22]:8:4,' ');
  END;
  READLN;
  WRITELN(FI);
  END;
  END;
  WRITELN(FI,'CONTOUR POINTS ON THE AIR-D INTERFACE ARE');
  WRITELN('CONTOUR POINTS ON THE AIR-D INTERFACE ARE');
  FOR I1:=1 TO NB DO
  BEGIN
  FOR I2:=1 TO 2 DO
  BEGIN
   PQE(NE+I1),I2]:=(RZE(NE+I1),I2]+RZE(EB+I1),I2])/2;
   WRITE(FI,PQE(NE+I1),I2]:8:4,' ');
   END;
   WRITELN(FI);
   END;
  WRITELN(FI);
  WRITELN('GIVE THE RELATIVE PERMEABILITY OF D');
  WRITELN(FI,'GIVE THE RELATIVE PERMEABILITY OF D');
  READLN(EP2);
  WRITELN(FI,EP2:8:4);
  WRITELN(FI);
{calculating the theta matrix
==================================================}
  FOR P1:=1 TO NB DO
  BEGIN
    IF (RZE(NE+P1),1]-RZE(EB+P1),1])=0.0 THEN
     TANQ1:=1.0E10
    ELSE
     TANQ1:=(RZENE+P1,2]-RZEEB+P1,2])/(RZENE+P1,1]-RZEEB+P1,1]);
    TH1EP1]:=ARCTAN(TANQ1);
  END;
   {------------------}
 FOR P1:=1 TO NB DO
 BEGIN
 SCEP1,1]:=ABS(SIN(TH1EP1]));
 SCEP1,2]:=ABS(COS(TH1EP1]))
 END;
  {-------------------------------}
  {calculating the potential matrix
  ================================================}
  IF (ED1>0.0) THEN
  BEGIN
   FOR X1:=1 TO ED1 DO
   BEGIN
    FOR Y1:=1 TO NE DO
```

```
    BEGIN
     MATEX1,Y1]:=(CO)*F(RZ,PG,Y1,X1);
    END;
    FOR Y1:=(NE+1) TO EB DO
    BEGIN
     MATEX1,Y1]:=0.0;
    END;
    FOR Y1:=(EB+1) TO EBB DO
    BEGIN
     MATEX1,Y1]:=(CO)*F(RZ,PG,Y1,X1);
    END;
   END;{OF ED1 ROWS CALCULATION}
  END;{OF ED1>0.0 }
{-------------------------------------------------------------}
FOR K1:=(ED1+1) TO NE DO
 BEGIN
  FOR L1:=1 TO NE DO
  BEGIN
   MATEK1,L1]:=(CO)*F(RZ,PG,L1,K1);
  END;
  FOR L1:=(NE+1) TO EB DO
  BEGIN
   MATEK1,L1]:=(CO)*F(RZ,PG,L1,K1);
  END;
  FOR L1:=(EB+1) TO EBB DO
  BEGIN
   MATEK1,L1]:=0.0;
  END;
 END;
{-------------------------------------------------------------}
 FOR M1:=(NE+1) TO EB DO
 BEGIN
  FOR N1:=1 TO NE DO
  BEGIN
   MATEM1,N1]:=0.0;
  END;
  FOR N1:=(NE+1) TO EB DO
  BEGIN
   MATEM1,N1]:=-(CO)*F(RZ,PG,N1,M1);
  END;
  FOR N1:=(EB+1) TO EBB DO
  BEGIN
   MATEM1,N1]:=(CO)*F(RZ,PG,N1,M1);
  END;
 END;
{-------------------------------------------------------------------}
FOR O1:=(EB+1) TO EBB DO
 BEGIN
 FOR R1:=1 TO NE DO
 BEGIN
  MATEO1,R1]:=(EP2-1)*(CO)*FS(RZ,PG,SC,R1,O1-NB,O1-EB)
 END;
 FOR R1:=(NE+1) TO EB DO
 BEGIN
  MATEO1,R1]:=EP2*CO*FS(RZ,PG,SC,R1,O1-NB,O1-EB)
 END;
  FOR R1:=(EB+1) TO EBB DO
  BEGIN
   MATEO1,R1]:=-(CO)*FS(RZ,PG,SC,R1,O1-NB,O1-EB)
  END;
 END;
{-------------------------------------------------------------------------}
```

```
FOR I:=1 TO EBB DO
BEGIN
 FOR J:=1 TO EB DO
 BEGIN
  WRITE(MATCI,JJ:8,' ');
 END;
  WRITELN;
END;
WRITELN('============================================================');
FOR I:=1 TO EBB DO
BEGIN
 FOR J:=(EB+1) TO EBB DO
 BEGIN
  WRITE(MATCI,JJ:8,' ')
 END;
 WRITELN
END;
{++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++}
inverse(mat,charge);
{++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++}
WRITELN(FI,'CHARGE VECTOR IS');
FOR C1:=1 TO N DO
BEGIN
 WRITELN(FI,CHARGECC1,1J:8);
 WRITELN(CHARGECC1,1J:6);
END;
{error calculation
==========================}
writeln(FI,'do you want to calculate the error. if yes then write 1 else write 0');
writeln('do you want to calculate the error. if yes then write 1 else write 0');
READLN(ANSO);
WRITELN(FI,ANSO);
IF ANSO= 1 THEN
BEGIN
WRITELN(FI,'GIVE THE NUMBER OF SUCH TEST POINTS ON THE AIR-E INTERFACE');
WRITELN('GIVE THE NUMBER OF SUCH TEST POINTS ON THE AIR-E INTERFACE');
READLN(H1);
IF H1>0.0 THEN
BEGIN
WRITELN(FI,'GIVE THE LOCATION OF SUCH POINTS');
WRITELN('GIVE THE LOCATION OF SUCH POINTS');
FOR H11:=1 TO H1 DO
BEGIN
FOR H12:=1 TO 2 DO
BEGIN
READ(ERRCH11,H12J);
WRITE(FI,ERRCH11,H12J:8:4,' ');
WRITE(ERRCH11,H12J:8:4,' ');
END;
READLN;
WRITELN ;
WRITELN(FI)
END;
END;
WRITELN(FI,'GIVE THE NUMBER OF TEST POINTS ON THE D-E INTERFACE');
WRITELN('GIVE THE NUMBER OF TEST POINTS ON THE D-E INTERFACE');
READLN(H2);
IF H2>0.0 THEN
BEGIN
WRITELN(FI,'GIVE THE LOCATION OF THESE TEST POINTS');
WRITELN('GIVE THE LOCATION OF THESE TEST POINTS');
FOR H21:=1 TO H2 DO
```

```
BEGIN
FOR H22:=1 TO 2 DO
BEGIN
READ(ERR[H21,H22]);
WRITE(ERR[H21,H22]:8:4,' ');
WRITE(FI,ERR[H21,H22]:8:4,' ');
END;
READLN;
WRITELN(FI);
WRITELN
END;
END;
FOR GI:=1 TO (H1+H2) DO
BEGIN
VOL[GI]:=0.0;
END;
IF H1>0.0 THEN
BEGIN
FOR G1:=1 TO H1 DO
BEGIN
FOR G2:=1 TO NE DO
BEGIN
VOL[G1]:=VOL[G1]+CO*FV(RZ,ERR,CHARGE,G2,G1)
END;
FOR G2:=(EB+1) TO EBB DO
BEGIN
VOL[G1]:=VOL[G1]+CO*FV(RZ,ERR,CHARGE,G2,G1)
END;
END;
END;
IF H2>0.0 THEN
BEGIN
FOR  G1:=(H1+1) TO (H1+H2) DO
BEGIN
FOR G2:=1 TO NE DO
BEGIN
VOL[G1]:=VOL[G1]+CO*FV(RZ,ERR,CHARGE,G2,G1)
END;
FOR G2:=(NE+1) TO EB DO
BEGIN
VOL[G1]:=VOL[G1]+CO*FV(RZ,ERR,CHARGE,G2,G1)
END;
END;
END;
WRITELN('THE ERROR VEVTOR IS');
WRITELN(FI,'THE ERROR VEVTOR IS');
CUM:=0.0;
FOR G1:=1 TO (H1+H2) DO
BEGIN
EROR[G1]:=VOL[G1]-1;
WRITELN(FI,EROR[G1]:8:4);
WRITELN(EROR[G1]:8:4);
CUM:=CUM+SQR(EROR[G1])
END;
WRITELN(FI,'CUMMULATIVE SQUARE ERROR IS');
WRITELN('CUMMULATIVE SQUARE ERROR IS');
WRITELN(FI,CUM:8:4);
WRITELN(CUM:8:4);
END;
WRITELN(FI,'END OF ERROR CALCULATION');
{END OF ERROR CALCULATION
=========================}
```

```
WRITELN('DO YOU WANT TO CALCULATE THE EQUIPOTENTIAL SURFACE. IF YES THEN');
WRITELN('WRITE 1 ELSE WRITE 0');
WRITELN(FI,'DO YOU WANT TO CALCULATE THE EQUIPOTENTIAL SURFACE. IF YES THEN');
WRITELN(FI,' WRITE 1 ELSE WRITE 0');
READLN(ANS1);
WRITELN(FI,ANS1);
WRITELN(ANS1);
IF ANS1=1 THEN
BEGIN
WRITELN(FI,'calculating the equipotential surface');
{calculating the equipotential surface
==========================================}
200: WRITELN(FI,'GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE');
     WRITELN('GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE');
     READLN(RIS,ZIS);
     WRITELN(FI,RIS:8:4,ZIS:8:4);
     WRITELN(FI,'GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE');
     WRITELN('GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE');
     READLN(RI,ZI);
     WRITELN(FI,RI:8:4,ZI:8:4);
     WRITELN(RI:8:4,ZI:8:4);

  WRITELN(FI,'GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE');
  WRITELN(FI,'STARTING POINT FALLS IN THE REGION:ax+by+c<=0');
  WRITELN('GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE');
  WRITELN('STARTING POINT FALLS IN THE REGION:ax+by+c<=0');
          WRITE('A=');
          READLN(A0);
          WRITELN(A0:8:4);
          WRITE('B=');
          READLN(B0);
          WRITELN(B0:8:4);
          WRITE('C=');
          READLN(C0);
          WRITELN(C0:8:4);
          WRITE(FI,'A=');
          WRITELN(FI,A0:8:4);
          WRITE(FI,'B=');
          WRITELN(FI,B0:8:4);
          WRITE(FI,'C=');
          WRITELN(FI,C0:8:4);
WRITELN('GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE');
WRITELN('STARTING POINT FALLS IN THE REGION:ax+by+c<=0');
          WRITE('A=');
          READLN(A2);
          WRITELN(A2:8:4);
          WRITE('B=');
          READLN(B2);
          WRITELN(B2:8:4);
          WRITE('C=');
          READLN(C2);
          WRITELN(C2:8:4);
WRITELN('GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT');
 READLN(EP);
WRITELN('GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE');
 READLN(DL);
WRITELN(DL:8:4);
WRITELN(FI,'GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE');
WRITELN(FI,'STARTING POINT FALLS IN THE REGION:ax+by+c<=0');
          WRITE(FI,'A=');
          WRITELN(FI,A2:8:4);
          WRITE(FI,'B=');
```

```
          WRITELN(FI,B2:8:4);
          WRITE(FI,'C=');
          WRITELN(FI,C2:8:4);
WRITELN(FI,'GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT');
WRITELN(FI,EP:8:4);
WRITELN(FI,'GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE');
WRITELN(FI,DL:8:4);
{-------------------------------------------------------------------------------}
500:IF ((A0*RI)+(B0*ZI)+C0) <0.0 THEN
BEGIN {OF FIRST IF LOOP}
 IF ((A2*RI)+(B2*ZI)+C2)<0.0 THEN
 BEGIN {OF SECOND IF LOOP}
  ER:=0.0;
  EZ:=0.0;
  FOR U:=1 TO NE DO
  BEGIN  {OF FOR LOOP}
   ER:=ER+(CO)*FER(RZ,CHARGE,RI,ZI,U);
   EZ:=EZ+(CO)*FEZ(RZ,CHARGE,RI,ZI,U);
  END;  {OF FOR LOOP}
 IF EP=EP2 THEN
 BEGIN {OF SECOND IF LOOP}
  FOR U:=(NE+1) TO EB DO
   BEGIN   {OF SECOND FOR LOOP}
    ER:=ER+(CO)*FER(RZ,CHARGE,RI,ZI,U);
    EZ:=EZ+(CO)*FEZ(RZ,CHARGE,RI,ZI,U);
   END;{OF SECOND FOR LOOP}
 END
 ELSE
 BEGIN
  FOR U:=(EB+1) TO EBF DO
   BEGIN
    ER:=ER+(CO)*FER(RZ,CHARGE,RI,ZI,U);
    EZ:=EZ+(CO)*FEZ(RZ,CHARGE,RI,ZI,U);
   END;
 END;{OF  SECOND IF LOOP}
 WRITELN('ER=',ER:8,' EZ=',EZ:8);
 IF ER=0.0 THEN
  BEGIN
   DZ:=0.0;
   DR:=DL;
   RI1:=RI+DR;
   RI2:=RI-DR;
   ZI:=ZI;
  RIE:=2*RI-RIS;
  ZIE:=2*ZI-ZIS;
  D1:=ABS(RI1-RIE);
  D2:=ABS(RI2-RIE)
  END
  ELSE
  BEGIN
   DZ:= DL/SQRT(1+SQR(EZ/ER));
   DR:=-(EZ/ER)*DZ;
   RI1:=RI+DR;
   RI2:=RI-DR;
   ZI1:=ZI+DZ;
   ZI2:=ZI-DZ;
   RIE:=2*RI-RIS;
   ZIE:=2*ZI-ZIS;
   D1:=SQR(RI1-RIE)+SQR(ZI1-ZIE);
   D2:=SQR(RI2-RIE)+SQR(ZI2-ZIE);
  END;
  RIS:=RI;
```

```
  ZIS:=ZI;
  IF D1<D2 THEN
  BEGIN
  RI:=RI1;
  ZI:=ZI1
  END
  ELSE
  BEGIN
  RI:=RI2;
  ZI:=ZI2
  END;
  IF (A0*RI)+(B0*ZI)+C0>0.00000 THEN
  BEGIN
  RIA:=(B0*(RIS*ZI-RI*ZIS)+C0*(RIS-RI))/(A0*(RI-RIS)+B0*(ZI-ZIS));
  ZIA:=(A0*(ZIS*RI-ZI*RIS)+C0*(ZIS-ZI))/(B0*(ZI-ZIS)+A0*(RI-RIS));
  WRITELN('RIA=',RIA:8:4,' ZIA=',ZIA:8:4);
  WRITELN(FI,'RIA=',RIA:8:4,' ZIA=',ZIA:8:4);
  END;
  IF (A2*RI)+(B2*ZI)+C2>0.00000 THEN
  BEGIN
  RIA:=(B2*(RIS*ZI-RI*ZIS)+C2*(RIS-RI))/(A2*(RI-RIS)+B2*(ZI-ZIS));
  ZIA:=(A2*(ZIS*RI-ZI*RIS)+C2*(ZIS-ZI))/(B2*(ZI-ZIS)+A2*(RI-RIS));
  WRITELN('RIA=',RIA:8:4,' ZIA=',ZIA:8:4);
  WRITELN(FI,'RIA=',RIA:8:4,' ZIA=',ZIA:8:4);
  END;
 WRITELN('RI=',RI:8:4,' ZI=',ZI:8:4);
 WRITELN;
 WRITELN(FI,'RI=',RI:8:4,' ZI=',ZI:8:4);
 GOTO 500;
END
ELSE
BEGIN
GOTO 400;
END;{OF OF SECOND IF LOOP}
END
ELSE
BEGIN
GOTO 400;
END;{OF FIRST IF LOOP}
400: WRITE('DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACE');
     WRITELN('IF YES THEN WRITE -1- ELSE WRITE-0-');
     WRITE(FI,'DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACE');
     WRITELN(FI,'IF YES THEN WRITE -1- ELSE WRITE-0-');
                  READLN(ANS);
                  WRITELN(FI,ANS);
                  IF ANS=1 THEN
                  GOTO 200
                  ELSE
                  GOTO 300;
END
ELSE
BEGIN
GOTO 300
END;
{=====================================================================}
writeln(fi,' calculation of tangential field component');
300: WRITELN('DO YOU WANT TO CALCULATE THE TANGENTIAL FIELD COMPONENTS');
     WRITELN('IF YES THEN WRITE 1 ELSE WRITE 0');
     WRITELN(FI,'DO YOU WANT TO CALCULATE THE TANGENTIAL FIELD COMPONENTS');
     WRITELN(FI,'IF YES THEN WRITE 1 ELSE WRITE 0');

     READLN(ANS3);
```

```
     WRITELN(FI,ANS3);
     WRITELN(ANS3);
IF ANS3=1 THEN
BEGIN
WRITELN(FI,'GIVE THE  NUMBER OF SUCH POINTS');
WRITELN('GIVE THE  NUMBER OF SUCH POINTS');
READLN(FJ,NOM);
WRITELN(FI,NOM);
WRITELN(NOM);
WRITELN(FI,'GIVE THE LOCATION AND SLOPE OF NORMAL AT SUCH POINTS ');
WRITELN('GIVE THE LOCATION AND SLOPE OF NORMAL AT SUCH POINTS ');
FOR MM:=1 TO NOM DO
BEGIN
FOR OO:=1 TO 3 DO
BEGIN
READ(FJ,HHCMM,OO);
WRITE(FI,HHCMM,OO:8:4,'  ');
END;
WRITELN(FI);
READLN(FJ);
END;
{-------------------------------------}
FOR MM:=1 TO NOM DO
BEGIN
CSCMM,1:=ABS(COS(ARCTAN(HHCMM,3)));
CSCMM,2:=ABS(SIN(ARCTAN(HHCMM,3)))
END;
{-------------------------------------}
WRITELN('TANGENTIAL FIELD VECTOR IS');
WRITELN(FI,'TANGENTIAL FIELD VECTOR IS');
FOR LO:=1 TO NOM DO
BEGIN
TANCLO:=0.0;
FOR PO:=1 TO NE DO
BEGIN
TANCLO:=TANCLO+ CO*CHARGECLO,1*FH(RZ,HH,CS,PO,LO);
END;
FOR PO:=(NE+1) TO EB DO
BEGIN
TANCLO:=TANCLO+CO*CHARGECLO,1*FH(RZ,HH,CS,PO,LO)
END;
WRITELN(FI,TANCLO:12:6);
WRITE(HHCLO,1:8:3,TANCLO:12:6);
WRITELN;
END;
END
ELSE
BEGIN
GOTO 600
END;
{-----------------------------------------------}
600:WRITELN(FI,'END OF EXECUTION ');
close(fi);
close(fj);
END.
```

INPUT FILE ≡ DAT.PRN

```
.35
.3
.25
.105 0.09
.105 0.01
.09 0.11
0.11
09 0.11
105 0.09
105 0.01
.095 0.09
.095 0.01
.09 0.09
0 0.09
09 0.09
095 0.09
095 0.01
0.4
.1 0.3
0.2
0.1 1E10
.01 0.1 1E10
.02 0.1 1E10
.03 0.1 1E10
.04 0.1 1E10
.05 0.1 1E10
.06 0.1 1E10
.07 0.1 1E10
.08 0.1 1E10
.09 0.1 1E10
```

CHARGE LOCATIONS INSIDE THE ELECTRODE

CHARGE LOCATIONS INSIDE THE AIR

CHARGE LOCATIONS IN THE DIELECTRIC

→ Number of Points on the electrode-Air interface (Contour points)

Location of Contour Points on the electrode-Air interface.

→ Number of Points on the Air-Dielectric interface where tangential Components of Electric field is desired.

Location of ~~6~~ Points on the Air-Dielectric interface where $E_{Tangential}$ is desired

```
GIVE THE LOCATION OF SIMULATION CHARGES INSIDE THE ELECTRODE
  0.0000    0.3500
  0.0000    0.3000
  0.0000    0.2500
GIVE THE LOCATION OF SIMULATION CHARGES INSIDE THE AIR
 -0.1050    0.0900
 -0.1050    0.0100
 -0.0900    0.1100
  0.0000    0.1100
  0.0900    0.1100
  0.1050    0.0900
  0.1050    0.0100
GIVE THE LOCATION OF SIMULATION CHARGES INSIDE THE DIELECTRIC
 -0.0950    0.0900
 -0.0950    0.0100
 -0.0900    0.0900
  0.0000    0.0900
  0.0900    0.0900
  0.0950    0.0900
  0.0950    0.0100

GIVE THE NUMBER OF CONTOUR POINTS ON  THE AIR-E INTERFACE
3
GIVE THE LOCATION OF ABOVE CONTOUR POINTS
  0.0000    0.4000
  0.1000    0.3000
  0.0000    0.2000
CONTOUR POINTS ON THE AIR-D INTERFACE ARE
 -0.1000    0.0900
 -0.1000    0.0100
 -0.0900    0.1000
  0.0000    0.1000
  0.0900    0.1000
  0.1000    0.0900
  0.1000    0.0100

GIVE THE RELATIVE PERMEABILITY OF D
  6.0000

CHARGE VECTOR IS
-1.2E-15
 1.1E-11
 1.5E-14
 9.4E-16
 6.4E-16
-1.5E-14
-2.0E-14
-1.5E-14
 9.4E-16
 6.4E-16
 8.7E-15
 8.7E-16
-2.2E-14
-2.0E-14
-2.2E-14
 8.7E-15
 8.7E-16
Do you want to calculate the error. If yes then write 1 else write 0
1
GIVE THE NUMBER OF SUCH TEST POINTS ON THE AIR-E INTERFACE
GIVE THE LOCATION OF SUCH POINTS
  0.0000    0.4000
```

```
  0.0701    0.3701
  0.1000    0.3000
  0.0701    0.2299
  0.0000    0.2000
GIVE THE NUMBER OF TEST POINTS ON THE D-E INTERFACE
THE ERROR VEVTOR IS
 -0.0000
  0.0088
 -0.0000
  0.0086
 -0.0000
CUMMULATIVE SQUARE ERROR IS
  0.0002
END OF ERROR CALCULATION
DO YOU WANT TO CALCULATE THE EQUIPOTENTIAL SURFACE. IF YES THEN
 WRITE 1 ELSE WRITE 0
1
calculating the equipotential surface
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0000  0.0200
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
  0.0000  0.0200
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.1000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.1000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  6.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0020
RI=  0.0020 ZI=  0.0200
RI=  0.0040 ZI=  0.0200
RI=  0.0060 ZI=  0.0200
RI=  0.0080 ZI=  0.0201
RI=  0.0100 ZI=  0.0201
RI=  0.0120 ZI=  0.0202
RI=  0.0140 ZI=  0.0203
RI=  0.0160 ZI=  0.0204
RI=  0.0180 ZI=  0.0205
RI=  0.0200 ZI=  0.0206
RI=  0.0220 ZI=  0.0208
RI=  0.0240 ZI=  0.0209
RI=  0.0260 ZI=  0.0211
RI=  0.0280 ZI=  0.0213
RI=  0.0300 ZI=  0.0215
RI=  0.0319 ZI=  0.0217
RI=  0.0339 ZI=  0.0219
RI=  0.0359 ZI=  0.0221
RI=  0.0379 ZI=  0.0224
RI=  0.0399 ZI=  0.0227
RI=  0.0419 ZI=  0.0229
RI=  0.0438 ZI=  0.0232
RI=  0.0458 ZI=  0.0235
RI=  0.0478 ZI=  0.0239
RI=  0.0498 ZI=  0.0242
RI=  0.0517 ZI=  0.0246
```

```
RI=  0.0537 ZI=  0.0249
RI=  0.0557 ZI=  0.0253
RI=  0.0576 ZI=  0.0257
RI=  0.0596 ZI=  0.0261
RI=  0.0615 ZI=  0.0265
RI=  0.0635 ZI=  0.0269
RI=  0.0654 ZI=  0.0274
RI=  0.0674 ZI=  0.0279
RI=  0.0693 ZI=  0.0283
RI=  0.0713 ZI=  0.0288
RI=  0.0732 ZI=  0.0293
RI=  0.0751 ZI=  0.0298
RI=  0.0771 ZI=  0.0304
RI=  0.0790 ZI=  0.0309
RI=  0.0809 ZI=  0.0315
RI=  0.0828 ZI=  0.0320
RI=  0.0847 ZI=  0.0326
RI=  0.0866 ZI=  0.0332
RI=  0.0886 ZI=  0.0338
RI=  0.0905 ZI=  0.0344
RI=  0.0923 ZI=  0.0351
RI=  0.0942 ZI=  0.0357
RI=  0.0961 ZI=  0.0364
RI=  0.0980 ZI=  0.0371
RI=  0.0999 ZI=  0.0378
RIA=  0.1000 ZIA=  0.0378
RI=  0.1018 ZI=  0.0385
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0999  0.0378
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
  0.1000  0.0378
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.2000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.3000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  1.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0020
RI=  0.1019 ZI=  0.0385
RI=  0.1037 ZI=  0.0392
RI=  0.1056 ZI=  0.0400
RI=  0.1075 ZI=  0.0407
RI=  0.1093 ZI=  0.0415
RI=  0.1112 ZI=  0.0422
RI=  0.1130 ZI=  0.0430
RI=  0.1148 ZI=  0.0438
RI=  0.1167 ZI=  0.0446
RI=  0.1185 ZI=  0.0454
RI=  0.1203 ZI=  0.0462
RI=  0.1221 ZI=  0.0471
RI=  0.1239 ZI=  0.0479
RI=  0.1257 ZI=  0.0488
RI=  0.1276 ZI=  0.0496
```

```
RI=  0.1293 ZI=  0.0505
RI=  0.1311 ZI=  0.0514
RI=  0.1329 ZI=  0.0523
RI=  0.1347 ZI=  0.0532
RI=  0.1365 ZI=  0.0542
RI=  0.1382 ZI=  0.0551
RI=  0.1400 ZI=  0.0561
RI=  0.1417 ZI=  0.0570
RI=  0.1435 ZI=  0.0580
RI=  0.1452 ZI=  0.0590
RI=  0.1469 ZI=  0.0600
RI=  0.1487 ZI=  0.0610
RI=  0.1504 ZI=  0.0621
RI=  0.1521 ZI=  0.0631
RI=  0.1538 ZI=  0.0642
RI=  0.1555 ZI=  0.0652
RI=  0.1572 ZI=  0.0663
RI=  0.1588 ZI=  0.0674
RI=  0.1605 ZI=  0.0685
RI=  0.1622 ZI=  0.0696
RI=  0.1638 ZI=  0.0707
RI=  0.1655 ZI=  0.0719
RI=  0.1671 ZI=  0.0730
RI=  0.1687 ZI=  0.0742
RI=  0.1703 ZI=  0.0754
RI=  0.1720 ZI=  0.0766
RI=  0.1736 ZI=  0.0778
RI=  0.1751 ZI=  0.0790
RI=  0.1767 ZI=  0.0802
RI=  0.1783 ZI=  0.0814
RI=  0.1799 ZI=  0.0827
RI=  0.1814 ZI=  0.0839
RI=  0.1830 ZI=  0.0852
RI=  0.1845 ZI=  0.0865
RI=  0.1860 ZI=  0.0878
RI=  0.1875 ZI=  0.0891
RI=  0.1891 ZI=  0.0904
RI=  0.1906 ZI=  0.0917
RI=  0.1920 ZI=  0.0931
RI=  0.1935 ZI=  0.0944
RI=  0.1950 ZI=  0.0958
RI=  0.1965 ZI=  0.0971
RI=  0.1979 ZI=  0.0985
RI=  0.1993 ZI=  0.0999
RIA=  0.2000 ZIA=  0.1005
RI=  0.2008 ZI=  0.1013
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0000  0.0400
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
  0.0000  0.0400
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.1000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.1000
```

```
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  6.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0020
RI=  0.0020 ZI=  0.0400
RI=  0.0040 ZI=  0.0400
RI=  0.0060 ZI=  0.0400
RI=  0.0080 ZI=  0.0401
RI=  0.0100 ZI=  0.0401
RI=  0.0120 ZI=  0.0402
RI=  0.0140 ZI=  0.0403
RI=  0.0160 ZI=  0.0404
RI=  0.0180 ZI=  0.0405
RI=  0.0200 ZI=  0.0407
RI=  0.0220 ZI=  0.0408
RI=  0.0240 ZI=  0.0410
RI=  0.0260 ZI=  0.0412
RI=  0.0280 ZI=  0.0414
RI=  0.0299 ZI=  0.0416
RI=  0.0319 ZI=  0.0418
RI=  0.0339 ZI=  0.0420
RI=  0.0359 ZI=  0.0423
RI=  0.0379 ZI=  0.0426
RI=  0.0399 ZI=  0.0428
RI=  0.0418 ZI=  0.0431
RI=  0.0438 ZI=  0.0435
RI=  0.0458 ZI=  0.0438
RI=  0.0478 ZI=  0.0441
RI=  0.0497 ZI=  0.0445
RI=  0.0517 ZI=  0.0449
RI=  0.0536 ZI=  0.0453
RI=  0.0556 ZI=  0.0457
RI=  0.0576 ZI=  0.0461
RI=  0.0595 ZI=  0.0465
RI=  0.0615 ZI=  0.0470
RI=  0.0634 ZI=  0.0475
RI=  0.0653 ZI=  0.0480
RI=  0.0673 ZI=  0.0485
RI=  0.0692 ZI=  0.0490
RI=  0.0711 ZI=  0.0495
RI=  0.0731 ZI=  0.0501
RI=  0.0750 ZI=  0.0506
RI=  0.0769 ZI=  0.0512
RI=  0.0788 ZI=  0.0518
RI=  0.0807 ZI=  0.0524
RI=  0.0826 ZI=  0.0530
RI=  0.0845 ZI=  0.0536
RI=  0.0864 ZI=  0.0543
RI=  0.0883 ZI=  0.0550
RI=  0.0902 ZI=  0.0556
RI=  0.0920 ZI=  0.0563
RI=  0.0939 ZI=  0.0570
RI=  0.0958 ZI=  0.0577
RI=  0.0976 ZI=  0.0585
RI=  0.0995 ZI=  0.0592
RIA=  0.1000 ZIA=  0.0594
RI=  0.1014 ZI=  0.0600
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
 1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0995  0.0592
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
```

```
  0.1000  0.0594
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.2000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.3000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  1.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0020
RI=  0.1019 ZI=  0.0601
RI=  0.1037 ZI=  0.0609
RI=  0.1056 ZI=  0.0617
RI=  0.1074 ZI=  0.0624
RI=  0.1093 ZI=  0.0632
RI=  0.1111 ZI=  0.0640
RI=  0.1129 ZI=  0.0648
RI=  0.1148 ZI=  0.0656
RI=  0.1166 ZI=  0.0664
RI=  0.1184 ZI=  0.0672
RI=  0.1202 ZI=  0.0681
RI=  0.1220 ZI=  0.0689
RI=  0.1238 ZI=  0.0698
RI=  0.1256 ZI=  0.0707
RI=  0.1274 ZI=  0.0716
RI=  0.1292 ZI=  0.0725
RI=  0.1309 ZI=  0.0734
RI=  0.1327 ZI=  0.0744
RI=  0.1345 ZI=  0.0754
RI=  0.1362 ZI=  0.0763
RI=  0.1379 ZI=  0.0773
RI=  0.1397 ZI=  0.0783
RI=  0.1414 ZI=  0.0794
RI=  0.1431 ZI=  0.0804
RI=  0.1448 ZI=  0.0814
RI=  0.1465 ZI=  0.0825
RI=  0.1482 ZI=  0.0836
RI=  0.1498 ZI=  0.0847
RI=  0.1515 ZI=  0.0858
RI=  0.1532 ZI=  0.0869
RI=  0.1548 ZI=  0.0881
RI=  0.1564 ZI=  0.0892
RI=  0.1581 ZI=  0.0904
RI=  0.1597 ZI=  0.0915
RI=  0.1613 ZI=  0.0927
RI=  0.1629 ZI=  0.0939
RI=  0.1645 ZI=  0.0952
RI=  0.1661 ZI=  0.0964
RI=  0.1676 ZI=  0.0976
RI=  0.1692 ZI=  0.0989
RI=  0.1707 ZI=  0.1001
RI=  0.1723 ZI=  0.1014
RI=  0.1738 ZI=  0.1027
RI=  0.1753 ZI=  0.1040
RI=  0.1768 ZI=  0.1053
RI=  0.1783 ZI=  0.1067
RI=  0.1798 ZI=  0.1080
```

```
RI=   0.1813 ZI=   0.1093
RI=   0.1827 ZI=   0.1107
RI=   0.1842 ZI=   0.1121
RI=   0.1856 ZI=   0.1135
RI=   0.1871 ZI=   0.1149
RI=   0.1885 ZI=   0.1163
RI=   0.1899 ZI=   0.1177
RI=   0.1913 ZI=   0.1191
RI=   0.1927 ZI=   0.1206
RI=   0.1941 ZI=   0.1220
RI=   0.1954 ZI=   0.1235
RI=   0.1968 ZI=   0.1250
RI=   0.1981 ZI=   0.1264
RI=   0.1995 ZI=   0.1279
RIA=  0.2000 ZIA=  0.1286
RI=   0.2008 ZI=   0.1294
```

```
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0000  0.0600
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
 #0.0000  0.0600
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.1000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.1000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  6.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0020
RI=  0.0020 ZI=  0.0600
RI=  0.0040 ZI=  0.0600
RI=  0.0060 ZI=  0.0600
RI=  0.0080 ZI=  0.0601
RI=  0.0100 ZI=  0.0601
RI=  0.0120 ZI=  0.0602
RI=  0.0140 ZI=  0.0603
RI=  0.0160 ZI=  0.0604
RI=  0.0180 ZI=  0.0605
RI=  0.0200 ZI=  0.0607
RI=  0.0220 ZI=  0.0608
RI=  0.0240 ZI=  0.0610
RI=  0.0260 ZI=  0.0612
RI=  0.0280 ZI=  0.0614
RI=  0.0299 ZI=  0.0616
RI=  0.0319 ZI=  0.0618
RI=  0.0339 ZI=  0.0621
RI=  0.0359 ZI=  0.0624
RI=  0.0379 ZI=  0.0626
RI=  0.0398 ZI=  0.0629
RI=  0.0418 ZI=  0.0633
RI=  0.0438 ZI=  0.0636
RI=  0.0458 ZI=  0.0640
RI=  0.0477 ZI=  0.0643
RI=  0.0497 ZI=  0.0647
RI=  0.0516 ZI=  0.0651
RI=  0.0536 ZI=  0.0656
RI=  0.0555 ZI=  0.0660
RI=  0.0575 ZI=  0.0665
RI=  0.0594 ZI=  0.0670
RI=  0.0614 ZI=  0.0675
RI=  0.0633 ZI=  0.0680
RI=  0.0652 ZI=  0.0685
RI=  0.0671 ZI=  0.0691
RI=  0.0691 ZI=  0.0697
RI=  0.0710 ZI=  0.0703
RI=  0.0729 ZI=  0.0709
RI=  0.0748 ZI=  0.0715
RI=  0.0767 ZI=  0.0722
RI=  0.0786 ZI=  0.0728
RI=  0.0804 ZI=  0.0735
RI=  0.0823 ZI=  0.0742
```

```
RI=  0.0842 ZI=  0.0749
RI=  0.0860 ZI=  0.0756
RI=  0.0879 ZI=  0.0764
RI=  0.0898 ZI=  0.0771
RI=  0.0916 ZI=  0.0779
RI=  0.0935 ZI=  0.0786
RI=  0.0953 ZI=  0.0794
RI=  0.0971 ZI=  0.0802
RI=  0.0990 ZI=  0.0809
RIA=  0.1000 ZIA=  0.0814
RI=  0.1008 ZI=  0.0817
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0990  0.0809
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
  0.1000  0.0814
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.2000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.3000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  1.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0020
RI=  0.1020 ZI=  0.0817
RI=  0.1039 ZI=  0.0822
RI=  0.1058 ZI=  0.0827
RI=  0.1077 ZI=  0.0834
RI=  0.1096 ZI=  0.0841
RI=  0.1115 ZI=  0.0848
RI=  0.1133 ZI=  0.0856
RI=  0.1151 ZI=  0.0864
RI=  0.1170 ZI=  0.0872
RI=  0.1188 ZI=  0.0881
RI=  0.1206 ZI=  0.0889
RI=  0.1224 ZI=  0.0898
RI=  0.1241 ZI=  0.0907
RI=  0.1259 ZI=  0.0917
RI=  0.1277 ZI=  0.0926
RI=  0.1294 ZI=  0.0936
RI=  0.1311 ZI=  0.0946
RI=  0.1329 ZI=  0.0956
RI=  0.1346 ZI=  0.0967
RI=  0.1363 ZI=  0.0977
RI=  0.1380 ZI=  0.0988
RI=  0.1397 ZI=  0.0999
RI=  0.1413 ZI=  0.1010
RI=  0.1430 ZI=  0.1021
RI=  0.1446 ZI=  0.1032
RI=  0.1463 ZI=  0.1044
RI=  0.1479 ZI=  0.1055
RI=  0.1495 ZI=  0.1067
RI=  0.1511 ZI=  0.1079
RI=  0.1527 ZI=  0.1091
RI=  0.1543 ZI=  0.1103
```

```
RI=  0.1559 ZI=  0.1115
RI=  0.1574 ZI=  0.1128
RI=  0.1590 ZI=  0.1141
RI=  0.1605 ZI=  0.1153
RI=  0.1621 ZI=  0.1166
RI=  0.1636 ZI=  0.1179
RI=  0.1651 ZI=  0.1192
RI=  0.1666 ZI=  0.1206
RI=  0.1681 ZI=  0.1219
RI=  0.1695 ZI=  0.1233
RI=  0.1710 ZI=  0.1246
RI=  0.1724 ZI=  0.1260
RI=  0.1739 ZI=  0.1274
RI=  0.1753 ZI=  0.1288
RI=  0.1767 ZI=  0.1302
RI=  0.1781 ZI=  0.1317
RI=  0.1795 ZI=  0.1331
RI=  0.1809 ZI=  0.1346
RI=  0.1822 ZI=  0.1360
RI=  0.1836 ZI=  0.1375
RI=  0.1849 ZI=  0.1390
RI=  0.1863 ZI=  0.1405
RI=  0.1876 ZI=  0.1420
RI=  0.1889 ZI=  0.1435
RI=  0.1902 ZI=  0.1450
RI=  0.1914 ZI=  0.1466
RI=  0.1927 ZI=  0.1481
RI=  0.1939 ZI=  0.1497
RI=  0.1952 ZI=  0.1513
RI=  0.1964 ZI=  0.1528
RI=  0.1976 ZI=  0.1544
RI=  0.1988 ZI=  0.1560
RI=  0.2000 ZI=  0.1577
RIA=  0.2000 ZIA=  0.1577
RI=  0.2012 ZI=  0.1593
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0000  0.0800
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
  0.0000  0.0800
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.1000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.1000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  6.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0020
RI=  0.0080 ZI=  0.0800
RI=  0.0040 ZI=  0.0830
RI=  0.0060 ZI=  0.0800
RI=  0.0080 ZI=  0.0850
RI=  0.0100 ZI=  0.0801
RI=  0.0120 ZI=  0.0801
RI=  0.0140 ZI=  0.0802
```

```
RI=  0.0160 ZI=  0.0803
RI=  0.0180 ZI=  0.0803
RI=  0.0200 ZI=  0.0804
RI=  0.0220 ZI=  0.0806
RI=  0.0240 ZI=  0.0807
RI=  0.0260 ZI=  0.0809
RI=  0.0280 ZI=  0.0811
RI=  0.0300 ZI=  0.0813
RI=  0.0319 ZI=  0.0815
RI=  0.0339 ZI=  0.0817
RI=  0.0359 ZI=  0.0820
RI=  0.0379 ZI=  0.0823
RI=  0.0399 ZI=  0.0826
RI=  0.0418 ZI=  0.0830
RI=  0.0438 ZI=  0.0833
RI=  0.0458 ZI=  0.0837
RI=  0.0477 ZI=  0.0841
RI=  0.0497 ZI=  0.0845
RI=  0.0516 ZI=  0.0850
RI=  0.0536 ZI=  0.0855
RI=  0.0555 ZI=  0.0860
RI=  0.0574 ZI=  0.0865
RI=  0.0594 ZI=  0.0870
RI=  0.0613 ZI=  0.0876
RI=  0.0632 ZI=  0.0882
RI=  0.0651 ZI=  0.0888
RI=  0.0670 ZI=  0.0895
RI=  0.0688 ZI=  0.0902
RI=  0.0707 ZI=  0.0909
RI=  0.0726 ZI=  0.0917
RI=  0.0744 ZI=  0.0925
RI=  0.0762 ZI=  0.0933
RI=  0.0780 ZI=  0.0942
RI=  0.0798 ZI=  0.0952
RI=  0.0815 ZI=  0.0962
RI=  0.0831 ZI=  0.0973
RI=  0.0847 ZI=  0.0985
RI=  0.0862 ZI=  0.0999
RIA=  0.0863 ZIA=  0.1000
RI=  0.0878 ZI=  0.1015
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0862  0.0999
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
  0.0863  0.1000
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.2000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.3000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  1.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0020
RI=  0.0862 ZI=  0.1017
RI=  0.0861 ZI=  0.1019
```

RI= 0.0921 ZI= 0.1016
RI= 0.0941 ZI= 0.1019
RI= 0.0960 ZI= 0.1022
RI= 0.0980 ZI= 0.1026
RI= 0.0999 ZI= 0.1031
RI= 0.1018 ZI= 0.1037
RI= 0.1037 ZI= 0.1043
RI= 0.1056 ZI= 0.1050
RI= 0.1075 ZI= 0.1058
RI= 0.1093 ZI= 0.1066
RI= 0.1111 ZI= 0.1074
RI= 0.1129 ZI= 0.1083
RI= 0.1147 ZI= 0.1092
RI= 0.1165 ZI= 0.1101
RI= 0.1182 ZI= 0.1111
RI= 0.1200 ZI= 0.1121
RI= 0.1217 ZI= 0.1131
RI= 0.1234 ZI= 0.1141
RI= 0.1251 ZI= 0.1152
RI= 0.1268 ZI= 0.1162
RI= 0.1285 ZI= 0.1173
RI= 0.1302 ZI= 0.1184
RI= 0.1318 ZI= 0.1195
RI= 0.1335 ZI= 0.1207
RI= 0.1351 ZI= 0.1218
RI= 0.1367 ZI= 0.1230
RI= 0.1383 ZI= 0.1242
RI= 0.1399 ZI= 0.1254
RI= 0.1415 ZI= 0.1266
RI= 0.1431 ZI= 0.1278
RI= 0.1446 ZI= 0.1291
RI= 0.1462 ZI= 0.1304
RI= 0.1477 ZI= 0.1316
RI= 0.1492 ZI= 0.1329
RI= 0.1507 ZI= 0.1343
RI= 0.1522 ZI= 0.1356
RI= 0.1537 ZI= 0.1369
RI= 0.1552 ZI= 0.1383
RI= 0.1567 ZI= 0.1396
RI= 0.1581 ZI= 0.1410
RI= 0.1595 ZI= 0.1424
RI= 0.1610 ZI= 0.1438
RI= 0.1624 ZI= 0.1452
RI= 0.1638 ZI= 0.1467
RI= 0.1651 ZI= 0.1481
RI= 0.1665 ZI= 0.1496
RI= 0.1679 ZI= 0.1511
RI= 0.1692 ZI= 0.1525
RI= 0.1705 ZI= 0.1540
RI= 0.1718 ZI= 0.1555
RI= 0.1731 ZI= 0.1571
RI= 0.1744 ZI= 0.1586
RI= 0.1757 ZI= 0.1601
RI= 0.1769 ZI= 0.1617
RI= 0.1782 ZI= 0.1633
RI= 0.1794 ZI= 0.1648
RI= 0.1806 ZI= 0.1664
RI= 0.1818 ZI= 0.1680
RI= 0.1830 ZI= 0.1697
RI= 0.1842 ZI= 0.1713
RI= 0.1853 ZI= 0.1729
RI= 0.1865 ZI= 0.1745

RI= 0.1876 ZI= 0.1762
RI= 0.1887 ZI= 0.1779
RI= 0.1898 ZI= 0.1795
RI= 0.1909 ZI= 0.1812
RI= 0.1920 ZI= 0.1829
RI= 0.1930 ZI= 0.1846
RI= 0.1940 ZI= 0.1863
RI= 0.1951 ZI= 0.1881
RI= 0.1961 ZI= 0.1898
RI= 0.1970 ZI= 0.1915
RI= 0.1980 ZI= 0.1933
RI= 0.1990 ZI= 0.1950
RI= 0.1999 ZI= 0.1968
RIA= 0.2000 ZIA= 0.1970
RI= 0.2008 ZI= 0.1986

```
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0000  0.0900
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
  0.0000  0.0900
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.1000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.1000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  6.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0020
RI=  0.0020 ZI=  0.0900
RI=  0.0040 ZI=  0.0900
RI=  0.0060 ZI=  0.0899
RI=  0.0080 ZI=  0.0899
RI=  0.0100 ZI=  0.0898
RI=  0.0120 ZI=  0.0898
RI=  0.0140 ZI=  0.0896
RI=  0.0160 ZI=  0.0897
RI=  0.0180 ZI=  0.0896
RI=  0.0200 ZI=  0.0898
RI=  0.0220 ZI=  0.0899
RI=  0.0240 ZI=  0.0900
RI=  0.0260 ZI=  0.0901
RI=  0.0280 ZI=  0.0902
RI=  0.0300 ZI=  0.0904
RI=  0.0320 ZI=  0.0906
RI=  0.0340 ZI=  0.0909
RI=  0.0359 ZI=  0.0911
RI=  0.0379 ZI=  0.0914
RI=  0.0399 ZI=  0.0917
RI=  0.0419 ZI=  0.0921
RI=  0.0438 ZI=  0.0924
RI=  0.0458 ZI=  0.0928
RI=  0.0477 ZI=  0.0933
RI=  0.0497 ZI=  0.0937
RI=  0.0516 ZI=  0.0942
RI=  0.0536 ZI=  0.0947
RI=  0.0555 ZI=  0.0952
RI=  0.0574 ZI=  0.0958
RI=  0.0593 ZI=  0.0964
RI=  0.0612 ZI=  0.0970
RI=  0.0631 ZI=  0.0976
RI=  0.0650 ZI=  0.0983
RI=  0.0669 ZI=  0.0990
RI=  0.0687 ZI=  0.0998
RIA=  0.0692 ZIA=  0.1000
RI=  0.0705 ZI=  0.1006
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0687  0.0998
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
```

```
  0.0692  0.1000
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.2000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.3000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  1.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0020
RI=  0.0710 ZI=  0.1008
RI=  0.0729 ZI=  0.1016
RI=  0.0747 ZI=  0.1024
RI=  0.0765 ZI=  0.1032
RI=  0.0784 ZI=  0.1040
RI=  0.0802 ZI=  0.1046
RI=  0.0821 ZI=  0.1055
RI=  0.0839 ZI=  0.1063
RI=  0.0858 ZI=  0.1070
RI=  0.0876 ZI=  0.1077
RI=  0.0895 ZI=  0.1084
RI=  0.0914 ZI=  0.1091
RI=  0.0932 ZI=  0.1098
RI=  0.0951 ZI=  0.1105
RI=  0.0970 ZI=  0.1112
RI=  0.0989 ZI=  0.1120
RI=  0.1007 ZI=  0.1128
RI=  0.1025 ZI=  0.1136
RI=  0.1044 ZI=  0.1144
RI=  0.1062 ZI=  0.1153
RI=  0.1079 ZI=  0.1162
RI=  0.1097 ZI=  0.1171
Rl=  0.1115 ZI=  0.1180
RI=  0.1132 ZI=  0.1190
RI=  0.1150 ZI=  0.1200
RI=  0.1167 ZI=  0.1210
RI=  0.1184 ZI=  0.1220
RI=  0.1201 ZI=  0.1231
RI=  0.1218 ZI=  0.1242
RI=  0.1235 ZI=  0.1253
RI=  0.1251 ZI=  0.1264
Rl=  0.1268 ZI=  0.1275
RI=  0.1284 ZI=  0.1286
RI=  0.1300 ZI=  0.1298
RI=  0.1317 ZI=  0.1310
RI=  0.1333 ZI=  0.1322
RI=  0.1348 ZI=  0.1334
RI=  0.1364 ZI=  0.1346
Rl=  0.1380 ZI=  0.1359
RI=  0.1395 ZI=  0.1372
Rl=  0.1411 ZI=  0.1384
RI=  0.1426 ZI=  0.1397
RI=  0.1441 ZI=  0.1410
Rl=  0.1456 ZI=  0.1424
Rl=  0.1471 ZI=  0.1437
Rl=  0.1486 ZI=  0.1451
RI=  1.1501 ZI=  0.1464
```

```
RI=  0.1515 ZI=  0.1478
RI=  0.1529 ZI=  0.1492
RI=  0.1543 ZI=  0.1506
RI=  0.1557 ZI=  0.1520
RI=  0.1571 ZI=  0.1535
RI=  0.1585 ZI=  0.1549
RI=  0.1599 ZI=  0.1564
RI=  0.1612 ZI=  0.1579
RI=  0.1625 ZI=  0.1593
RI=  0.1639 ZI=  0.1608
RI=  0.1652 ZI=  0.1624
RI=  0.1665 ZI=  0.1639
RI=  0.1677 ZI=  0.1654
RI=  0.1690 ZI=  0.1670
RI=  0.1702 ZI=  0.1685
RI=  0.1715 ZI=  0.1701
RI=  0.1727 ZI=  0.1717
RI=  0.1739 ZI=  0.1733
RI=  0.1751 ZI=  0.1749
RI=  0.1763 ZI=  0.1765
RI=  0.1774 ZI=  0.1782
RI=  0.1786 ZI=  0.1798
RI=  0.1797 ZI=  0.1815
RI=  0.1808 ZI=  0.1831
RI=  0.1819 ZI=  0.1848
RI=  0.1830 ZI=  0.1865
RI=  0.1840 ZI=  0.1882
RI=  0.1851 ZI=  0.1899
RI=  0.1861 ZI=  0.1916
RI=  0.1871 ZI=  0.1933
RI=  0.1881 ZI=  0.1951
RI=  0.1891 ZI=  0.1968
RI=  0.1901 ZI=  0.1985
RI=  0.1910 ZI=  0.2003
RI=  0.1919 ZI=  0.2021
RI=  0.1929 ZI=  0.2039
RI=  0.1938 ZI=  0.2056
RI=  0.1946 ZI=  0.2074
RI=  0.1955 ZI=  0.2092
RI=  0.1963 ZI=  0.2111
RI=  0.1972 ZI=  0.2129
RI=  0.1980 ZI=  0.2147
RI=  0.1988 ZI=  0.2165
RI=  0.1996 ZI=  0.2184
RIA=  0.2000 ZIA=  0.2194
RI=  0.2003 ZI=  0.2202
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0000  0.1200
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
  0.0000  0.1200
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.2000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.2000
```

```
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  1.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0020
RI=  0.0020 ZI=  0.1200
RI=  0.0040 ZI=  0.1200
RI=  0.0060 ZI=  0.1200
RI=  0.0080 ZI=  0.1201
RI=  0.0100 ZI=  0.1201
RI=  0.0120 ZI=  0.1202
RI=  0.0140 ZI=  0.1203
RI=  0.0160 ZI=  0.1204
RI=  0.0180 ZI=  0.1205
RI=  0.0200 ZI=  0.1207
RI=  0.0220 ZI=  0.1209
RI=  0.0240 ZI=  0.1211
RI=  0.0260 ZI=  0.1213
RI=  0.0279 ZI=  0.1215
RI=  0.0299 ZI=  0.1218
RI=  0.0319 ZI=  0.1221
RI=  0.0339 ZI=  0.1224
RI=  0.0358 ZI=  0.1228
RI=  0.0378 ZI=  0.1231
RI=  0.0398 ZI=  0.1235
RI=  0.0417 ZI=  0.1239
RI=  0.0437 ZI=  0.1244
RI=  0.0456 ZI=  0.1248
RI=  0.0476 ZI=  0.1253
RI=  0.0495 ZI=  0.1258
RI=  0.0514 ZI=  0.1264
RI=  0.0534 ZI=  0.1269
RI=  0.0553 ZI=  0.1275
RI=  0.0572 ZI=  0.1281
RI=  0.0591 ZI=  0.1287
RI=  0.0610 ZI=  0.1293
RI=  0.0629 ZI=  0.1300
RI=  0.0647 ZI=  0.1307
RI=  0.0666 ZI=  0.1314
RI=  0.0685 ZI=  0.1321
RI=  0.0703 ZI=  0.1328
RI=  0.0722 ZI=  0.1336
RI=  0.0740 ZI=  0.1344
RI=  0.0759 ZI=  0.1352
RI=  0.0777 ZI=  0.1360
RI=  0.0795 ZI=  0.1368
RI=  0.0813 ZI=  0.1377
RI=  0.0831 ZI=  0.1385
RI=  0.0849 ZI=  0.1394
RI=  0.0867 ZI=  0.1403
RI=  0.0885 ZI=  0.1413
RI=  0.0902 ZI=  0.1422
RI=  0.0920 ZI=  0.1432
RI=  0.0937 ZI=  0.1442
RI=  0.0954 ZI=  0.1452
RI=  0.0972 ZI=  0.1462
RI=  0.0989 ZI=  0.1472
RI=  0.1006 ZI=  0.1483
RI=  0.1022 ZI=  0.1494
RI=  0.1039 ZI=  0.1505
RI=  0.1056 ZI=  0.1516
RI=  0.1072 ZI=  0.1528
RI=  0.1088 ZI=  0.1539
```

RI= 0.1105 ZI= 0.1551
RI= 0.1121 ZI= 0.1563
RI= 0.1136 ZI= 0.1575
RI= 0.1152 ZI= 0.1587
RI= 0.1168 ZI= 0.1600
RI= 0.1183 ZI= 0.1612
RI= 0.1199 ZI= 0.1625
RI= 0.1214 ZI= 0.1638
RI= 0.1229 ZI= 0.1651
RI= 0.1244 ZI= 0.1665
RI= 0.1259 ZI= 0.1678
RI= 0.1273 ZI= 0.1692
RI= 0.1288 ZI= 0.1706
RI= 0.1302 ZI= 0.1720
RI= 0.1316 ZI= 0.1734
RI= 0.1330 ZI= 0.1748
RI= 0.1344 ZI= 0.1763
RI= 0.1357 ZI= 0.1777
RI= 0.1371 ZI= 0.1792
RI= 0.1384 ZI= 0.1807
RI= 0.1397 ZI= 0.1822
RI= 0.1410 ZI= 0.1837
RI= 0.1423 ZI= 0.1853
RI= 0.1436 ZI= 0.1868
RI= 0.1448 ZI= 0.1884
RI= 0.1460 ZI= 0.1900
RI= 0.1473 ZI= 0.1916
RI= 0.1485 ZI= 0.1932
RI= 0.1496 ZI= 0.1948
RI= 0.1508 ZI= 0.1964
RI= 0.1519 ZI= 0.1981
RI= 0.1530 ZI= 0.1997
RI= 0.1541 ZI= 0.2014
RI= 0.1552 ZI= 0.2031
RI= 0.1563 ZI= 0.2048
RI= 0.1573 ZI= 0.2065
RI= 0.1584 ZI= 0.2082
RI= 0.1594 ZI= 0.2099
RI= 0.1604 ZI= 0.2116
RI= 0.1613 ZI= 0.2134
RI= 0.1623 ZI= 0.2152
RI= 0.1632 ZI= 0.2169
RI= 0.1641 ZI= 0.2187
RI= 0.1650 ZI= 0.2205
RI= 0.1659 ZI= 0.2223
RI= 0.1668 ZI= 0.2241
RI= 0.1676 ZI= 0.2259
RI= 0.1684 ZI= 0.2277
RI= 0.1692 ZI= 0.2296
RI= 0.1700 ZI= 0.2314
RI= 0.1707 ZI= 0.2332
RI= 0.1715 ZI= 0.2351
RI= 0.1722 ZI= 0.2370
RI= 0.1729 ZI= 0.2389
RI= 0.1735 ZI= 0.2408
RI= 0.1742 ZI= 0.2427
RI= 0.1748 ZI= 0.2446
RI= 0.1754 ZI= 0.2465
RI= 0.1760 ZI= 0.2484
RI= 0.1765 ZI= 0.2503
RI= 0.1771 ZI= 0.2522
RI= 0.1776 ZI= 0.2541

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RI=  0.1781 ZI=  0.2561
RI=  0.1786 ZI=  0.2580
RI=  0.1791 ZI=  0.2600
RI=  0.1795 ZI=  0.2619
RI=  0.1799 ZI=  0.2639
RI=  0.1803 ZI=  0.2658
RI=  0.1807 ZI=  0.2678
RI=  0.1811 ZI=  0.2698
RI=  0.1814 ZI=  0.2717
RI=  0.1817 ZI=  0.2737
RI=  0.1820 ZI=  0.2757
RI=  0.1823 ZI=  0.2777
RI=  0.1825 ZI=  0.2797
RI=  0.1827 ZI=  0.2817
RI=  0.1829 ZI=  0.2836
RI=  0.1831 ZI=  0.2856
RI=  0.1833 ZI=  0.2876
RI=  0.1834 ZI=  0.2896
RI=  0.1835 ZI=  0.2916
RI=  0.1836 ZI=  0.2936
RI=  0.1837 ZI=  0.2956
RI=  0.1838 ZI=  0.2976
RI=  0.1838 ZI=  0.2996
RIA=  0.1838 ZIA=  0.3000
RI=  0.1836 ZI=  0.3016

DO YOU WANT TO CALCULATE THE EQUIPOTENTIAL SURFACE. IF YES THEN
 WRITE 1 ELSE WRITE 0
1
calculating the equipotential surface
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0000  0.1400
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
  0.0000  0.1400
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.2000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.3000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  1.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0030
RI=  0.0030 ZI=  0.1400
RI=  0.0060 ZI=  0.1401
RI=  0.0090 ZI=  0.1402
RI=  0.0120 ZI=  0.1403
RI=  0.0150 ZI=  0.1405
RI=  0.0180 ZI=  0.1406
RI=  0.0210 ZI=  0.1411
RI=  0.0239 ZI=  0.1415
RI=  0.0269 ZI=  0.1419
RI=  0.0299 ZI=  0.1424
RI=  0.0328 ZI=  0.1429
RI=  0.0358 ZI=  0.1435
RI=  0.0387 ZI=  0.1442
RI=  0.0416 ZI=  0.1449
RI=  0.0445 ZI=  0.1456
```

RI= 0.0474 ZI= 0.1465
RI= 0.0503 ZI= 0.1473
RI= 0.0531 ZI= 0.1482
RI= 0.0560 ZI= 0.1492
RI= 0.0588 ZI= 0.1502
RI= 0.0616 ZI= 0.1513
RI= 0.0644 ZI= 0.1525
RI= 0.0671 ZI= 0.1536
RI= 0.0698 ZI= 0.1549
RI= 0.0726 ZI= 0.1562
RI= 0.0752 ZI= 0.1575
RI= 0.0779 ZI= 0.1589
RI= 0.0805 ZI= 0.1603
RI= 0.0832 ZI= 0.1618
RI= 0.0857 ZI= 0.1633
RI= 0.0883 ZI= 0.1649
RI= 0.0908 ZI= 0.1665
RI= 0.0933 ZI= 0.1682
RI= 0.0958 ZI= 0.1699
RI= 0.0982 ZI= 0.1717
RI= 0.1006 ZI= 0.1735
RI= 0.1029 ZI= 0.1753
RI= 0.1053 ZI= 0.1772
RI= 0.1076 ZI= 0.1792

```
RI=  0.1098 ZI=  0.1811
RI=  0.1120 ZI=  0.1832
RI=  0.1142 ZI=  0.1852
RI=  0.1163 ZI=  0.1873
RI=  0.1184 ZI=  0.1895
RI=  0.1205 ZI=  0.1917
RI=  0.1225 ZI=  0.1939
RI=  0.1245 ZI=  0.1961
RI=  0.1264 ZI=  0.1984
RI=  0.1283 ZI=  0.2008
RI=  0.1301 ZI=  0.2031
RI=  0.1319 ZI=  0.2055
RI=  0.1337 ZI=  0.2080
RI=  0.1354 ZI=  0.2104
RI=  0.1371 ZI=  0.2129
RI=  0.1387 ZI=  0.2155
RI=  0.1402 ZI=  0.2180
RI=  0.1418 ZI=  0.2206
RI=  0.1432 ZI=  0.2232
RI=  0.1447 ZI=  0.2259
RI=  0.1460 ZI=  0.2285
RI=  0.1474 ZI=  0.2312
RI=  0.1486 ZI=  0.2339
RI=  0.1499 ZI=  0.2367
RI=  0.1510 ZI=  0.2394
RI=  0.1522 ZI=  0.2422
RI=  0.1532 ZI=  0.2450
RI=  0.1542 ZI=  0.2478
RI=  0.1552 ZI=  0.2507
RI=  0.1561 ZI=  0.2535
RI=  0.1570 ZI=  0.2564
RI=  0.1578 ZI=  0.2593
RI=  0.1585 ZI=  0.2622
RI=  0.1592 ZI=  0.2651
RI=  0.1599 ZI=  0.2681
RI=  0.1605 ZI=  0.2710
RI=  0.1610 ZI=  0.2739
RI=  0.1615 ZI=  0.2769
RI=  0.1619 ZI=  0.2799
RI=  0.1623 ZI=  0.2829
RI=  0.1626 ZI=  0.2858
RI=  0.1629 ZI=  0.2888
RI=  0.1631 ZI=  0.2918
RI=  0.1632 ZI=  0.2948
RI=  0.1633 ZI=  0.2978
RIA=  0.1634 ZIA=  0.3000
RI=  0.1634 ZI=  0.3008
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0000  0.1600
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
  0.0000  0.1600
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.2000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
```

C= -0.3000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
1.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
0.0030
RI= 0.0030 ZI= 0.1600
RI= 0.0060 ZI= 0.1601
RI= 0.0090 ZI= 0.1602
RI= 0.0120 ZI= 0.1604
RI= 0.0150 ZI= 0.1606
RI= 0.0180 ZI= 0.1609
RI= 0.0209 ZI= 0.1613
RI= 0.0239 ZI= 0.1618
RI= 0.0269 ZI= 0.1623
RI= 0.0298 ZI= 0.1628
RI= 0.0327 ZI= 0.1635
RI= 0.0357 ZI= 0.1642
RI= 0.0386 ZI= 0.1649
RI= 0.0415 ZI= 0.1657
RI= 0.0443 ZI= 0.1666
RI= 0.0472 ZI= 0.1675
RI= 0.0500 ZI= 0.1685
RI= 0.0528 ZI= 0.1696
RI= 0.0556 ZI= 0.1707
RI= 0.0584 ZI= 0.1719
RI= 0.0611 ZI= 0.1731
RI= 0.0638 ZI= 0.1744
RI= 0.0665 ZI= 0.1758
RI= 0.0691 ZI= 0.1772
RI= 0.0717 ZI= 0.1786
RI= 0.0743 ZI= 0.1801
RI= 0.0769 ZI= 0.1817
RI= 0.0794 ZI= 0.1833
RI= 0.0819 ZI= 0.1850
RI= 0.0843 ZI= 0.1868
RI= 0.0868 ZI= 0.1885
RI= 0.0891 ZI= 0.1904
RI= 0.0915 ZI= 0.1923
RI= 0.0938 ZI= 0.1942
RI= 0.0960 ZI= 0.1962
RI= 0.0982 ZI= 0.1982
RI= 0.1004 ZI= 0.2003
RI= 0.1025 ZI= 0.2024
RI= 0.1046 ZI= 0.2046
RI= 0.1066 ZI= 0.2068
RI= 0.1086 ZI= 0.2090
RI= 0.1105 ZI= 0.2113
RI= 0.1124 ZI= 0.2137
RI= 0.1142 ZI= 0.2160
RI= 0.1160 ZI= 0.2185
RI= 0.1177 ZI= 0.2209
RI= 0.1194 ZI= 0.2234
RI= 0.1211 ZI= 0.2259
RI= 0.1226 ZI= 0.2285
RI= 0.1241 ZI= 0.2311
RI= 0.1256 ZI= 0.2337
RI= 0.1270 ZI= 0.2363
RI= 0.1284 ZI= 0.2390
RI= 0.1296 ZI= 0.2417
RI= 0.1309 ZI= 0.2444
RI= 0.1321 ZI= 0.2472
RI= 0.1332 ZI= 0.2500

```
RI=  0.1342 ZI=  0.2528
RI=  0.1352 ZI=  0.2556
RI=  0.1362 ZI=  0.2585
RI=  0.1370 ZI=  0.2613
RI=  0.1379 ZI=  0.2642
RI=  0.1386 ZI=  0.2671
RI=  0.1393 ZI=  0.2701
RI=  0.1400 ZI=  0.2730
RI=  0.1405 ZI=  0.2759
RI=  0.1410 ZI=  0.2789
RI=  0.1415 ZI=  0.2819
RI=  0.1419 ZI=  0.2848
RI=  0.1422 ZI=  0.2878
RI=  0.1424 ZI=  0.2908
RI=  0.1426 ZI=  0.2938
RI=  0.1428 ZI=  0.2968
RI=  0.1428 ZI=  0.2998
RIA=  0.1428 ZIA=  0.3000
RI=  0.1428 ZI=  0.3028
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0000  0.1800
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
  0.0000  0.1800
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  1.0000
B=  0.0000
C= -0.2000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=  0.0000
B=  1.0000
C= -0.3000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  1.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0030
RI=  0.0030 ZI=  0.1800
RI=  0.0060 ZI=  0.1801
RI=  0.0090 ZI=  0.1802
RI=  0.0120 ZI=  0.1804
RI=  0.0150 ZI=  0.1807
RI=  0.0180 ZI=  0.1811
RI=  0.0209 ZI=  0.1816
RI=  0.0239 ZI=  0.1821
RI=  0.0268 ZI=  0.1827
RI=  0.0297 ZI=  0.1834
RI=  0.0326 ZI=  0.1841
RI=  0.0355 ZI=  0.1849
RI=  0.0384 ZI=  0.1858
RI=  0.0412 ZI=  0.1867
RI=  0.0441 ZI=  0.1877
RI=  0.0469 ZI=  0.1888
RI=  0.0496 ZI=  0.1900
RI=  0.0524 ZI=  0.1912
RI=  0.0551 ZI=  0.1925
RI=  0.0577 ZI=  0.1939
RI=  0.0604 ZI=  0.1953
RI=  0.0630 ZI=  0.1968
RI=  0.0655 ZI=  0.1984
```

```
RI=   0.0681 ZI=   0.2000
RI=   0.0705 ZI=   0.2017
RI=   0.0730 ZI=   0.2034
RI=   0.0754 ZI=   0.2051
RI=   0.0777 ZI=   0.2071
RI=   0.0800 ZI=   0.2090
RI=   0.0822 ZI=   0.2110
RI=   0.0845 ZI=   0.2130
RI=   0.0867 ZI=   0.2151
RI=   0.0888 ZI=   0.2173
RI=   0.0908 ZI=   0.2194
RI=   0.0928 ZI=   0.2217
RI=   0.0947 ZI=   0.2240
RI=   0.0966 ZI=   0.2263
RI=   0.0984 ZI=   0.2287
RI=   0.1002 ZI=   0.2311
RI=   0.1019 ZI=   0.2336
RI=   0.1035 ZI=   0.2361
RI=   0.1051 ZI=   0.2387
RI=   0.1066 ZI=   0.2413
RI=   0.1081 ZI=   0.2439
RI=   0.1095 ZI=   0.2465
RI=   0.1106 ZI=   0.2492
RI=   0.1120 ZI=   0.2520
RI=   0.1132 ZI=   0.2547
RI=   0.1143 ZI=   0.2575
RI=   0.1154 ZI=   0.2603
RI=   0.1164 ZI=   0.2631
RI=   0.1173 ZI=   0.2659
RI=   0.1181 ZI=   0.2688
RI=   0.1189 ZI=   0.2718
RI=   0.1196 ZI=   0.2747
RI=   0.1202 ZI=   0.2776
RI=   0.1207 ZI=   0.2806
RI=   0.1212 ZI=   0.2836
RI=   0.1216 ZI=   0.2865
RI=   0.1220 ZI=   0.2895
RI=   0.1222 ZI=   0.2925
RI=   0.1224 ZI=   0.2955
RI=   0.1225 ZI=   0.2985
RIA=   0.1225 ZIA=   0.3000
RI=   0.1226 ZI=   0.3015
DO YOU WANT TO CALCULATE THE EQUIPOTENTIAL SURFACE. IF YES THEN
 WRITE 1 ELSE WRITE 0
1
calculating the equipotential surface
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
   0.0000   0.2000
GIVE THE EXTENTION POINT OF THE EQUIPOTENTIAL SURFACE
   0.0000   0.2000
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :ax+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=   1.0000
B=   0.0000
C=  -0.2000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:ax+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:ax+by+c<=0
A=   0.0000
B=   1.0000
C=  -0.3000
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
   1.0000
```

```
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0200
RI=  0.0200 ZI=  0.2000
RI=  0.0396 ZI=  0.2079
RI=  0.0581 ZI=  0.2119
RI=  0.0748 ZI=  0.2133
RI=  0.0868 ZI=  0.2134
RI=  0.1038 ZI=  0.2127
RI=  0.1093 ZI=  0.2106
RI=  0.1149 ZI=  0.2091
RI=  0.1162 ZI=  0.2100
RI=  0.1145 ZI=  0.2100
RI=  0.1095 ZI=  0.2092
RI=  0.1015 ZI=  0.2075
RI=  0.0908 ZI=  0.2062
RI=  0.0765 ZI=  0.2086
RIA=  0.0760 ZIA=  0.2990
RI=  0.0657 ZI=  0.4111
DO YOU WANT TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
1
GIVE THE INITIAL POINT OF THE DESIRED EQUIPOTENTIAL SURFACE
  0.0000  0.2000
GIVE THE EXTERNAL POINT OF THE EQUIPOTENTIAL SURFACE
  0.0000  0.2000
GIVE THE CONSTANTS OF THE FIRST BOUNDARY LINE :a.+by+c=0  SUCH THAT THE
STARTING POINT FALLS IN THE REGION:a.+by+c.=0
A=  1.0000
B=  1.0000
C= -0.2000
GIVE THE CONSTANTS OF THE SECOND BOUNDARY LINE:a.+by+c=0 SUCH THAT THE
STARTING POINT FALLS IN THE REGION:a.+by+c.=0
A=  0.0000
B=  1.0000
C= -0.3990
GIVE THE RELATIVE PERMEABILITY OF THE INITIAL POINT
  1.0000
GIVE THE LENGTH OF INFINITSIMAL ELEMENT ALONG THE EQUIPOTENTIAL SURFACE
  0.0020
RI=  0.0020 ZI=  0.2000
RI=  0.0040 ZI=  0.2000
RI=  0.0060 ZI=  0.2001
RI=  0.0080 ZI=  0.2002
RI=  0.0100 ZI=  0.2004
RI=  0.0120 ZI=  0.2006
RI=  0.0140 ZI=  0.2008
RI=  0.0160 ZI=  0.2011
RI=  0.0179 ZI=  0.2014
RI=  0.0199 ZI=  0.2018
RI=  0.0219 ZI=  0.2022
RI=  0.0239 ZI=  0.2026
RI=  0.0259 ZI=  0.2031
RI=  0.0279 ZI=  0.2036
RI=  0.0299 ZI=  0.2042
RI=  0.0319 ZI=  0.2048
RI=  0.0338 ZI=  0.2054
RI=  0.0358 ZI=  0.2060
RI=  0.0378 ZI=  0.2067
RI=  0.0398 ZI=  0.2074
RI=  0.0418 ZI=  0.2081
RI=  0.0438 ZI=  0.2088
RI=  0.0458 ZI=  0.2096
RI=  0.0478 ZI=  0.2104
```

RI= 0.0481 ZI= 0.2118
RI= 0.0496 ZI= 0.2127
RI= 0.0516 ZI= 0.2137
RI= 0.0536 ZI= 0.2147
RI= 0.0552 ZI= 0.2156
RI= 0.0566 ZI= 0.2169
RI= 0.0582 ZI= 0.2180
RI= 0.0599 ZI= 0.2192
RI= 0.0615 ZI= 0.2204
RI= 0.0631 ZI= 0.2216
RI= 0.0647 ZI= 0.2228
RI= 0.0662 ZI= 0.2241
RI= 0.0677 ZI= 0.2254
RI= 0.0692 ZI= 0.2268
RI= 0.0707 ZI= 0.2282
RI= 0.0721 ZI= 0.2296
RI= 0.0735 ZI= 0.2310
RI= 0.0748 ZI= 0.2324
RI= 0.0762 ZI= 0.2339
RI= 0.0775 ZI= 0.2354
RI= 0.0788 ZI= 0.2370
RI= 0.0800 ZI= 0.2385
RI= 0.0812 ZI= 0.2401
RI= 0.0824 ZI= 0.2417
RI= 0.0836 ZI= 0.2434
RI= 0.0847 ZI= 0.2450
RI= 0.0858 ZI= 0.2467
RI= 0.0869 ZI= 0.2484
RI= 0.0879 ZI= 0.2501
RI= 0.0889 ZI= 0.2519
RI= 0.0899 ZI= 0.2536
RI= 0.0907 ZI= 0.2554
RI= 0.0916 ZI= 0.2572
RI= 0.0925 ZI= 0.2590
RI= 0.0933 ZI= 0.2608
RI= 0.0941 ZI= 0.2627
RI= 0.0948 ZI= 0.2645
RI= 0.0955 ZI= 0.2664
RI= 0.0962 ZI= 0.2683
RI= 0.0968 ZI= 0.2702
RI= 0.0974 ZI= 0.2721
RI= 0.0979 ZI= 0.2740
RI= 0.0984 ZI= 0.2760
RI= 0.0989 ZI= 0.2779
RI= 0.0993 ZI= 0.2798
RI= 0.0997 ZI= 0.2818
RI= 0.1001 ZI= 0.2838
RI= 0.1004 ZI= 0.2857
RI= 0.1007 ZI= 0.2877
RI= 0.1009 ZI= 0.2897
RI= 0.1012 ZI= 0.2917
RI= 0.1013 ZI= 0.2937
RI= 0.1014 ZI= 0.2957
RI= 0.1015 ZI= 0.2977
RI= 0.1016 ZI= 0.2997
RI= 0.1016 ZI= 0.3017
RI= 0.1015 ZI= 0.3037
RI= 0.1015 ZI= 0.3057
RI= 0.1014 ZI= 0.3077
RI= 0.1013 ZI= 0.3097
RI= 0.1011 ZI= 0.3117

```
RI= [illegible] ZI= 0.3156
RI= 0.1002 ZI= 0.3176
RI= [illegible] ZI= 0.3196
RI= [illegible] ZI= 0.3215
RI= [illegible] ZI= [illegible]
RI= [illegible] ZI= 0.3254
RI= [illegible] ZI= 0.3274
RI= 0.0976 ZI= 0.3293
RI= 0.0970 ZI= 0.3312
RI= 0.0964 ZI= 0.3331
RI= 0.0957 ZI= 0.3350
RI= 0.0950 ZI= 0.3369
RI= 0.0943 ZI= 0.3388
RI= 0.0936 ZI= 0.3406
RI= 0.0926 ZI= 0.3425
RI= 0.0919 ZI= 0.3443
RI= 0.0911 ZI= 0.3461
RI= 0.0902 ZI= 0.3479
RI= 0.0892 ZI= 0.3496
RI= [illegible] ZI= [illegible]
RI= 0.0872 ZI= 0.3531
RI= 0.0862 ZI= 0.3548
RI= [illegible] ZI= 0.3565
RI= 0.0840 ZI= 0.3582
RI= 0.0829 ZI= 0.3598
RI= [illegible] ZI= 0.3614
RI= [illegible] ZI= 0.3630
RI= [illegible] ZI= 0.3646
RI= 0.0780 ZI= 0.3662
RI= [illegible] ZI= 0.3677
RI= [illegible] ZI= 0.3692
RI= 0.0740 ZI= 0.3707
RI= 0.0727 ZI= 0.3721
RI= 0.0713 ZI= 0.3735
RI= 0.0698 ZI= 0.3749
RI= 0.0684 ZI= 0.3763
RI= 0.0669 ZI= 0.3776
RI= 0.0654 ZI= 0.3789
RI= 0.0638 ZI= 0.3802
RI= 0.0622 ZI= 0.3814
RI= 0.0607 ZI= 0.3826
RI= 0.0590 ZI= 0.3838
RI= 0.0574 ZI= 0.3850
RI= 0.0558 ZI= 0.3861
RI= 0.0541 ZI= 0.3872
RI= 0.0524 ZI= 0.3882
RI= 0.0507 ZI= 0.3893
RI= 0.0489 ZI= 0.3903
RI= 0.0472 ZI= 0.3912
RI= 0.0454 ZI= 0.3921
RI= 0.0436 ZI= 0.3930
RI= 0.0418 ZI= 0.3939
RI= 0.0399 ZI= 0.3947
RI= 0.0381 ZI= 0.3954
RI= 0.0362 ZI= 0.3962
RI= 0.0344 ZI= 0.3969
RI= 0.0325 ZI= [illegible]
RI= [illegible] ZI= 0.3982
RI= [illegible] ZI= [illegible]
RI= [illegible] ZIA= [illegible]
[illegible]
[illegible] TO CALCULATE MORE EQUIPOTENTIAL SURFACEIF YES THEN WRITE -1- ELSE WRITE-0-
C
```

TANGENTIAL FIELD CALCULATION

```
DO YOU WANT TO CALCULATE THE TANGENTIAL FIELD COMPONENTS
IF YES THEN WRITE 1 ELSE WRITE 0
1
GIVE THE  NUMBER OF SUCH POINTS
10
GIVE THE LOCATION AND SLOPE OF NORMAL AT SUCH POINTS
  0.0000     0.1000   10000000000.0000
  0.0100     0.1000   10000000000.0000
  0.0200     0.1000   10000000000.0000
  0.0300     0.1000   10000000000.0000
  0.0400     0.1000   10000000000.0000
  0.0500     0.1000   10000000000.0000
  0.0600     0.1000   10000000000.0000
  0.0700     0.1000   10000000000.0000
  0.0800     0.1000   10000000000.0000
  0.0900     0.1000   10000000000.0000
{----------------------------------------}
Er=4
TANGENTIAL FIELD VECTOR IS
   -0.091615
  356.420084
    0.106885
    0.002207
    0.000854
   -0.016162
   -0.034436
   -0.074796
    0.019159
    0.039238
{--------------------------------------}
Er=6
TANGENTIAL FIELD VECTOR IS
   -0.108789
  356.452848
    0.127197
    0.002924
    0.001031
   -0.019305
   -0.041022
   -0.089340
    0.025388
    0.047371
{----------------------------------------}
Er=8
TANGENTIAL FIELD VECTOR IS
   -0.118267
  356.470924
    0.138461
    0.003367
    0.001132
   -0.021057
   -0.044685
   -0.097446
    0.029236
    0.051992
{------------------------------------------------}
Er=10
TANGENTIAL FIELD VECTOR IS
   -0.124871
  356.482375
    0.145619
    0.003666
```

FIGURES

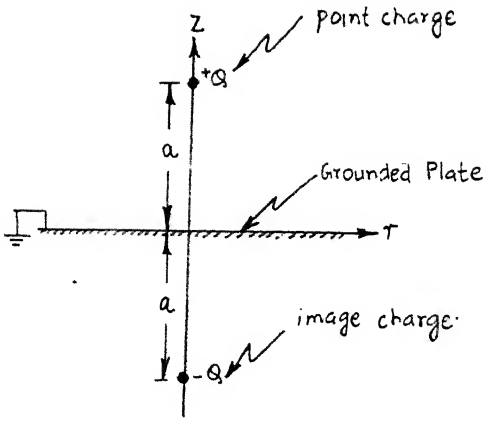

fig.1. Point Charge and grounded Conducting Plate (or Earth)

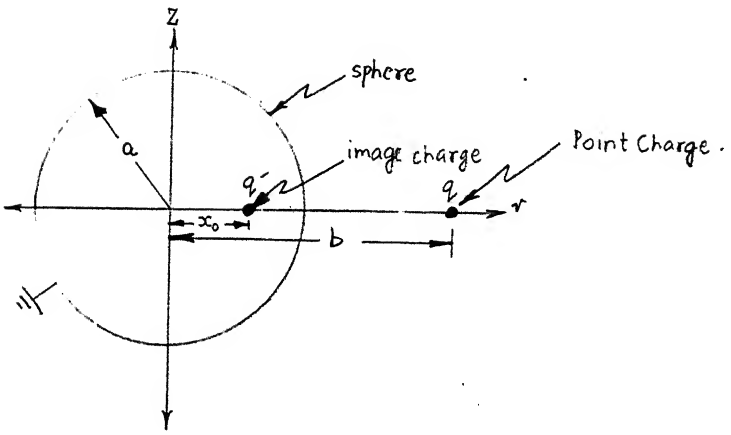

fig.2. Grounded Conducting Sphere and a Point Charge Outside it.

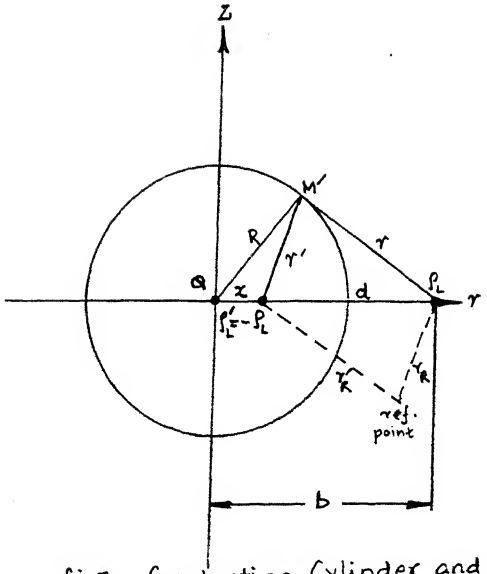

fig3. Conducting Cylinder and a line Charge.

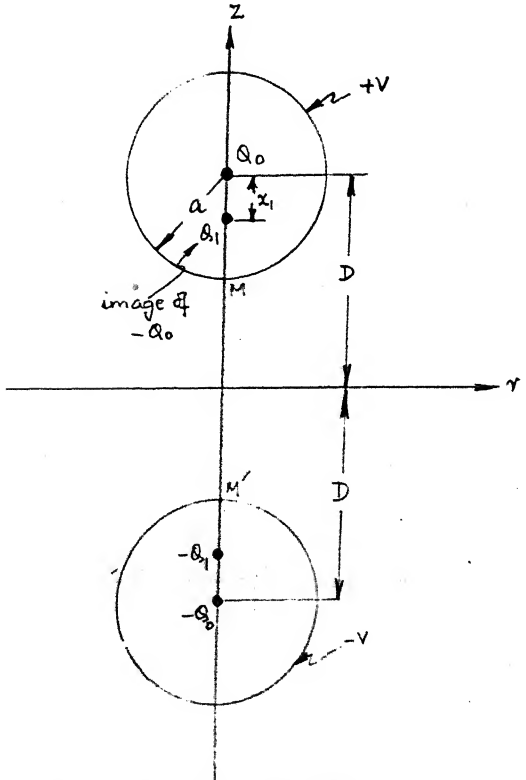

fig4. Spherical electrodes

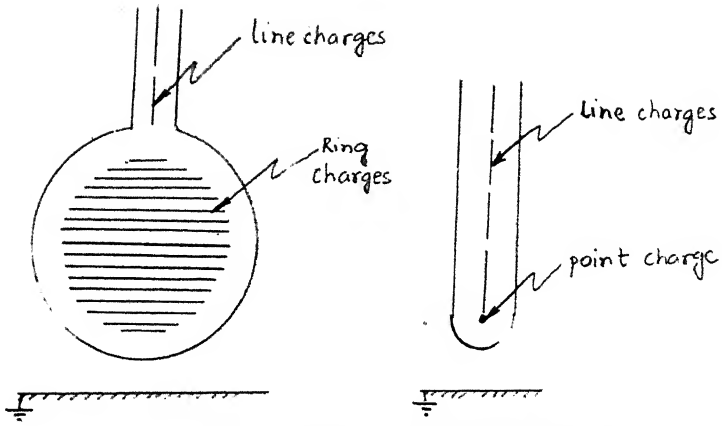

fig.5. Representation Of Surfaces Using Point, Line and Ring charges.

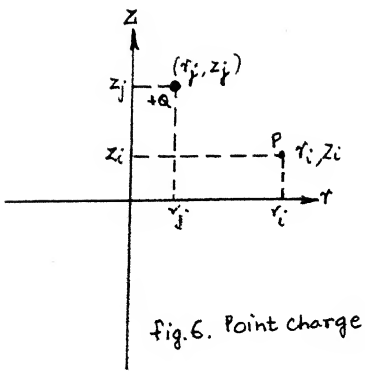

fig.6. Point charge

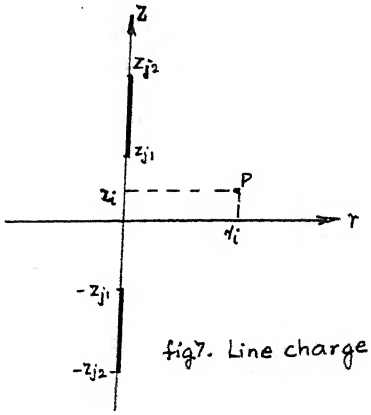

fig7. Line charge

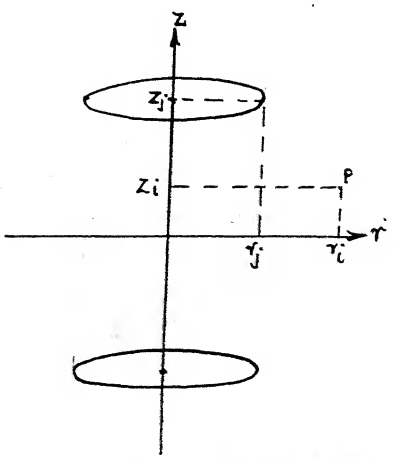

fig. 8. Ring Charge

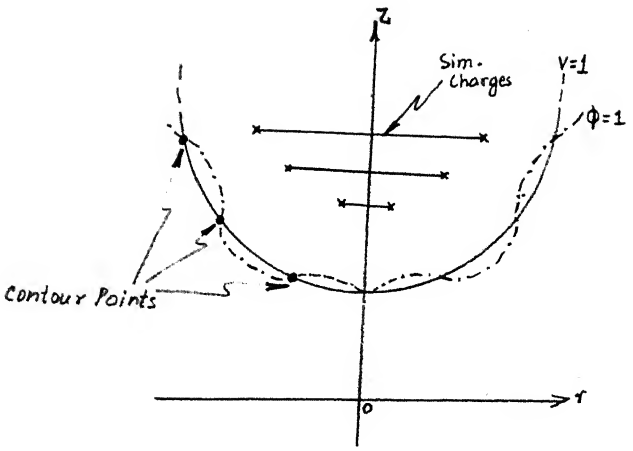

fig.9. Comparision of an existing, —, and a simulated, —·—, surface of an electrode.

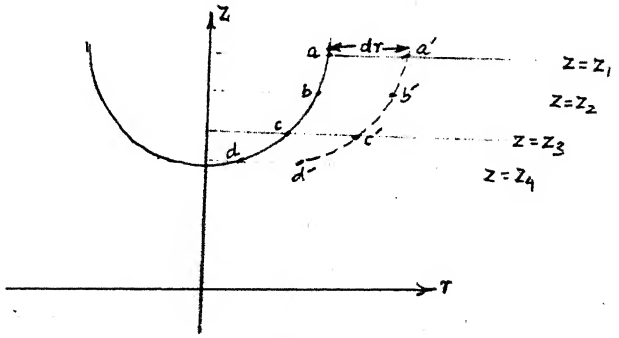

fig.10. Equipotential Surface Plotting

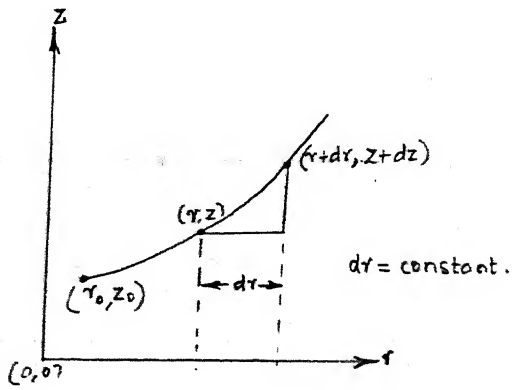

fig.11. Equipotential Surface Plotting.

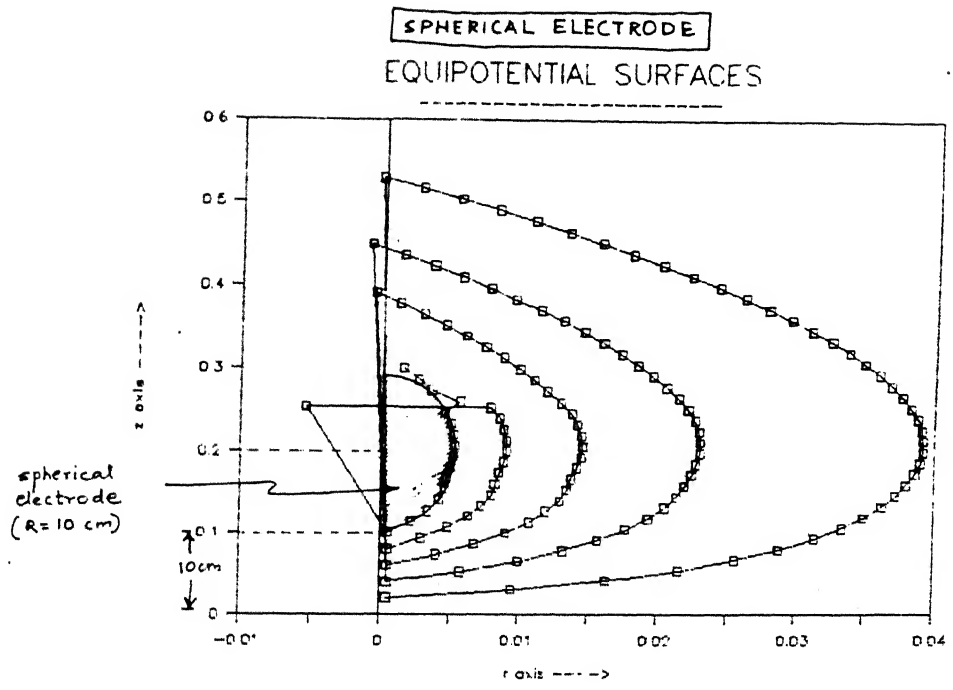
SPHERICAL ELECTRODE
EQUIPOTENTIAL SURFACES
spherical electrode (R = 10 cm)
10cm
z axis
r axis
0.6
0.5
0.4
0.3
0.2
0.1
0
0.01
0.02
0.03
0.04

fig. 12.

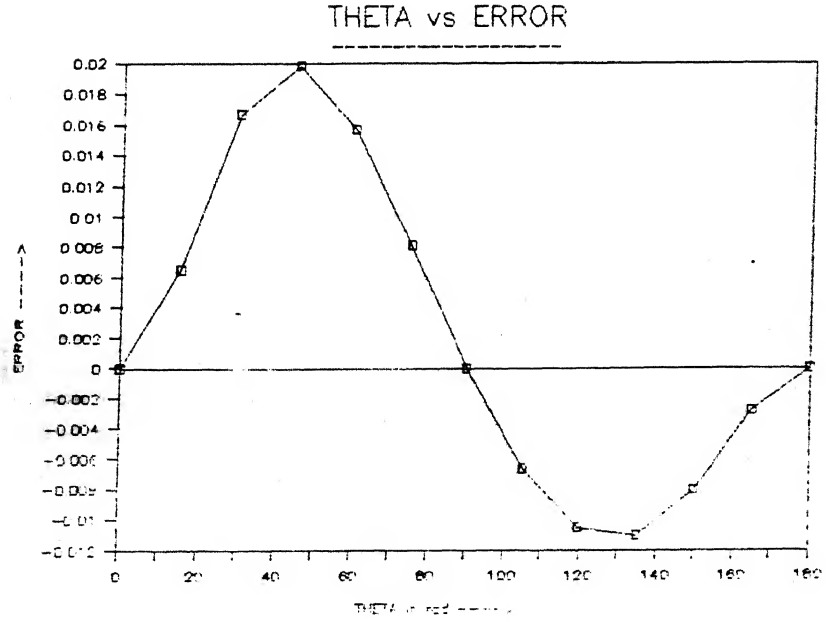
THETA vs ERROR
ERROR
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
0
20
40
60
80
100
120
140
160
180

fig. 13.

ROD-ROD CASE

EQUIPOTENTIAL SURFACES {G = 30 cm. / R = 1 cm.}

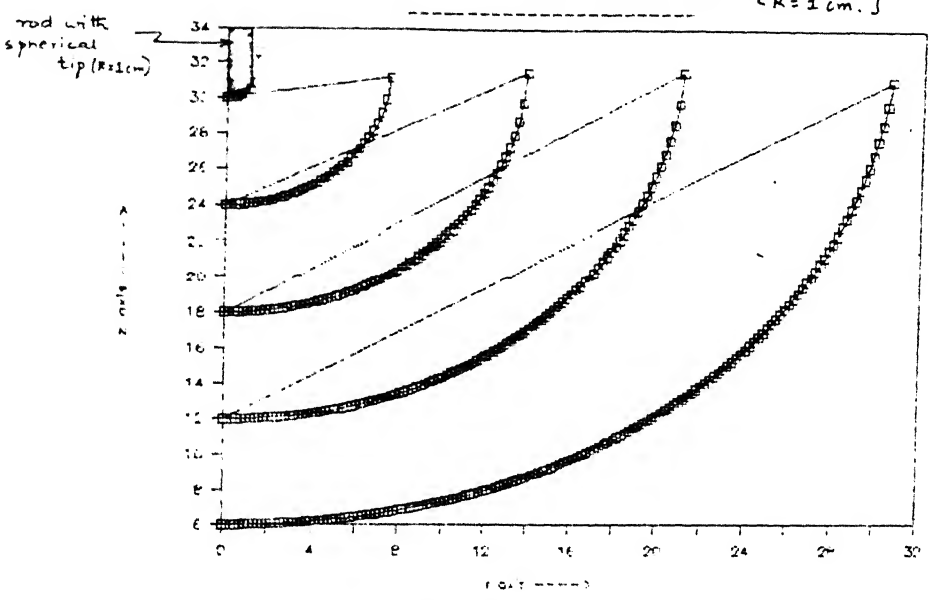

fig. 14

ERROR ALONG THE CYLINDRICAL PART

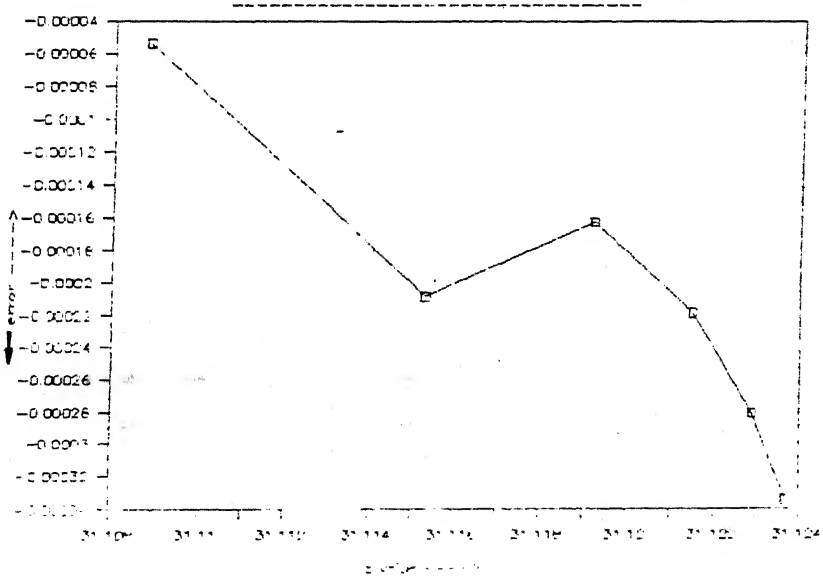

fig. 15

NO OF CHARGES vs ERROR

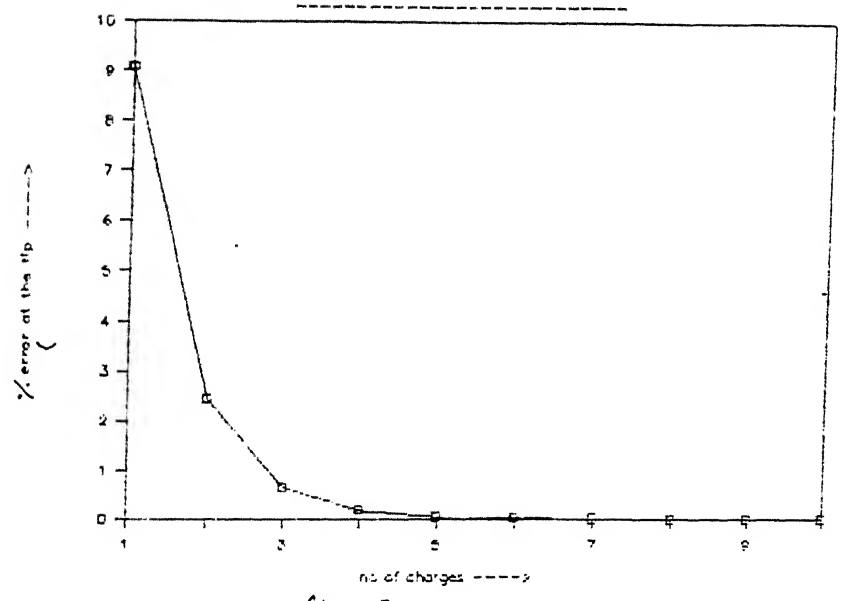

fig · 16

ROGOWSKI SURFACE

EQUIPOTENTIAL SURFACES

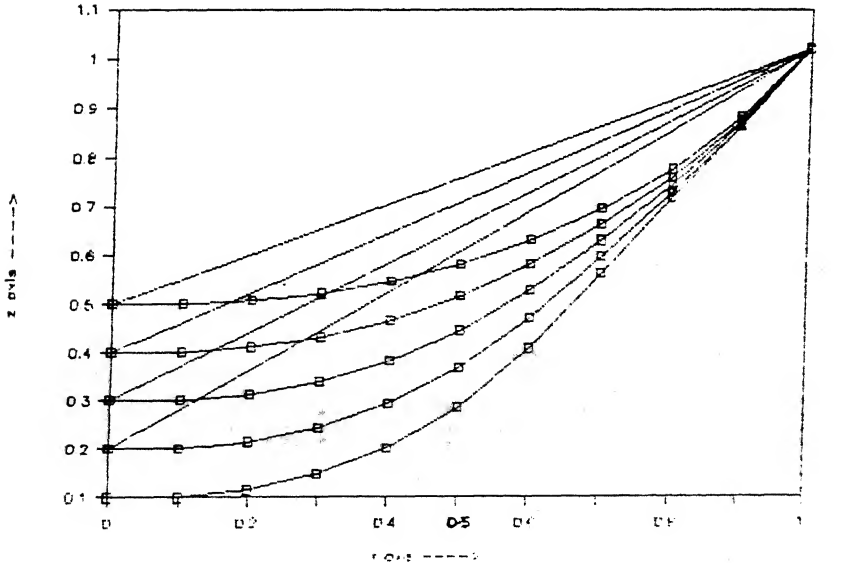

fig · 17

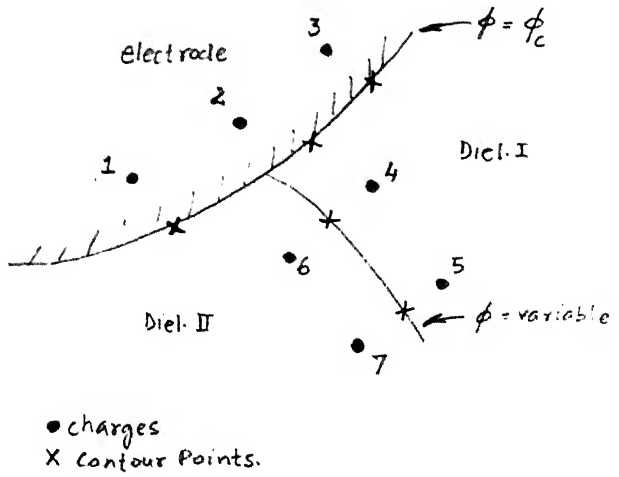

fig. 18 Simulation of dielectric boundary by discrete charges.

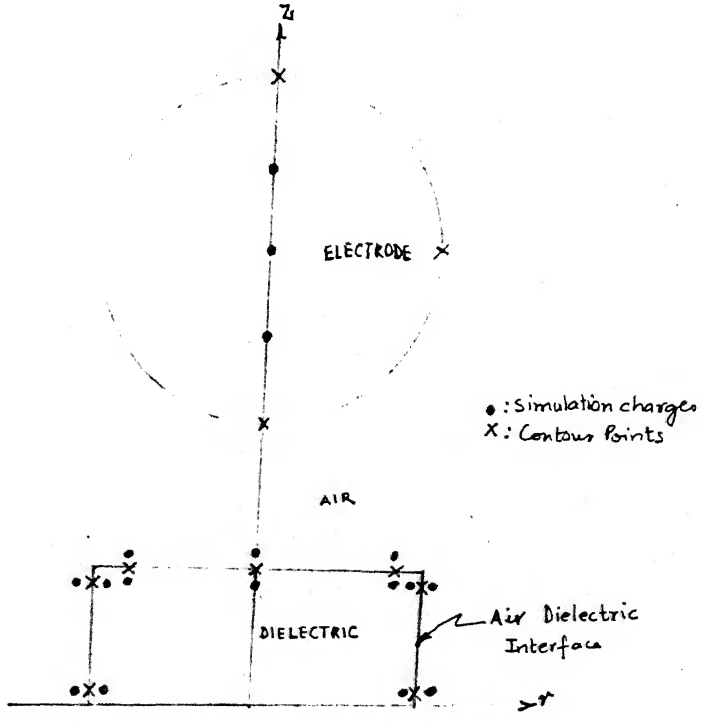

fig. 19. The multidielectric case sample problem

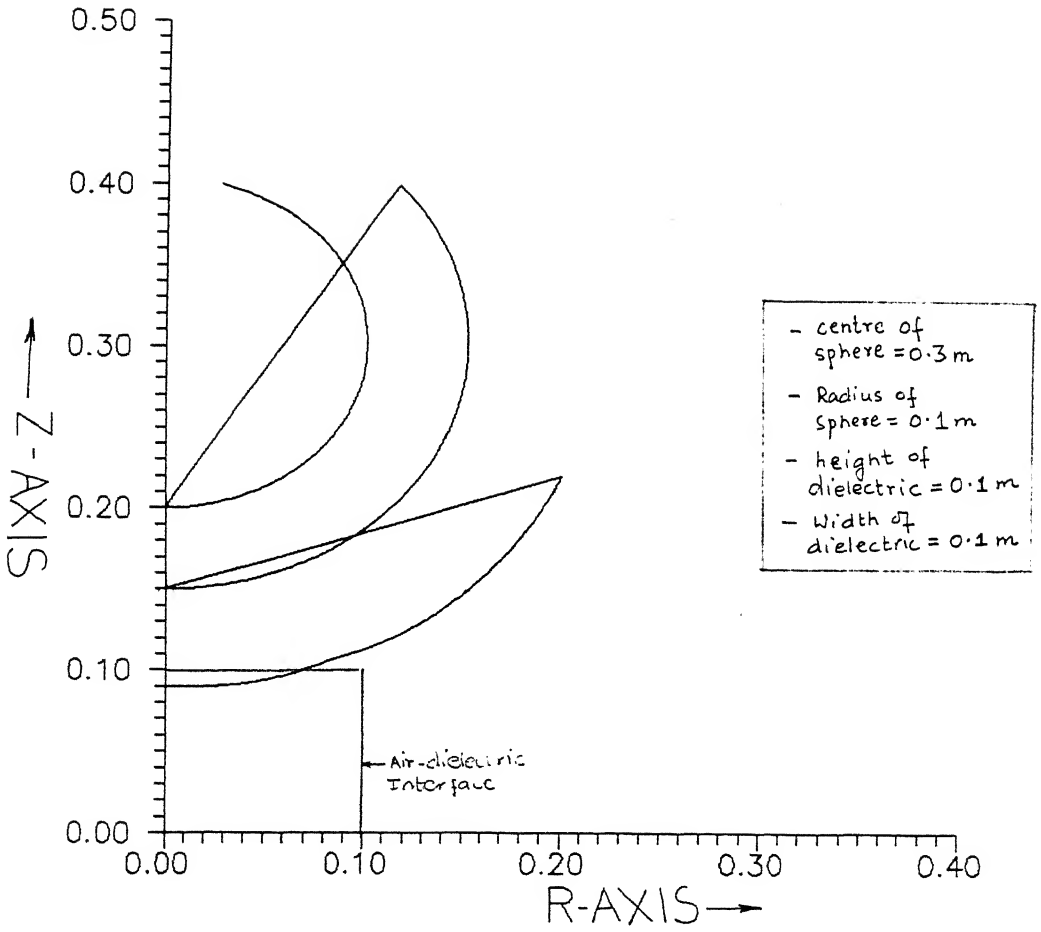

fig.20 Equipotential Surface for the sphere-dielectric problem

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